New York State Education Department

NEW YORK STATE MUSEUM

63d ANNUAL REPORT

1909

In 4 volumes

VOLUME 1

REPORT OF THE DIRECTOR 1909

AND

APPENDIX 1

TRANSMITTED TO THE LEGISLATURE FEBRUARY 21, 1910

ALBANY
UNIVERSITY OF THE STATE OF NEW YORK
1911

STATE OF NEW YORK

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STATE OF NEW YORK

No. 45

IN ASSEMBLY

FEBRUARY 21, 1910

63d ANNUAL REPORT

OF THE

NEW YORK STATE MUSEUM

VOLUME 1

To the Legislature of the State of New York

We have the honor to submit herewith, pursuant to law, as the 63d Annual Report of the New York State Museum, the report of the Director, including the reports of the State Geologist and State Paleontologist, and the reports of the State Entomologist and the State Botanist, with appendixes.

ST CLAIR MCKELWAY
Vice Chancellor of the University

ANDREW S. DRAPER
Commissioner of Education

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Education Department Bulletin

Published fortnightly by the University of the State of New York

Entered as second-class matter June 24, 1908, at the Post Office at Albany, N. Y., under the act of July 16, 1894

No. 473 | ALBANY, N. Y. | JUNE 15, 1910

New York State Museum

JOHN M. CLARKE, Director

Museum Bulletin 140

SIXTH REPORT OF THE DIRECTOR OF THE SCIENCE DIVISION

INCLUDING THE

63D REPORT OF THE STATE MUSEUM, THE 29TH REPORT OF THE STATE GEOLOGIST, AND THE REPORT OF THE STATE PALEONTOLOGIST FOR 1909

New York State Education Department
Science Division, February 15, 1910

Hon. Andrew S. Draper LL.D.
Commissioner of Education

SIR: I communicate to you herewith for publication as a bulletin of the State Museum, the *Sixth Annual Report of the Director of the Science Division* for the fiscal year ending September 30, 1909.

Very respectfully
JOHN M. CLARKE
Director

State of New York
Education Department
COMMISSIONER'S ROOM

Approved for publication this 21st day of February 1910

A. S. Draper

Commissioner of Education

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DIRECTOR'S REPORT FOR 1909

INTRODUCTION

This report covers all divisions of the scientific work under the charge of the Education Department and concerns the progress made therein during the fiscal year 1908–9. It constitutes the 63d annual report of the State Museum and is introductory to all the scientific memoirs, bulletins and other publications issued from this office during the year mentioned.

Under the action of the Regents of the University (April 26, 1904) the work of the Science Division is "under the immediate supervision of the Commissioner of Education," and the advisory committee of the Board of Regents of the University having the affairs of this division in charge are the Honorables: T. Guilford Smith LL.D., Buffalo; Daniel Beach LL.D., Watkins; Lucian L. Shedden LL.D., Plattsburg.

The subjects to be presented in this report are considered under the following chapters:

I Condition of the scientific collections

II Report on the Geological Survey, including the work of the State Geologist and Paleontologist, of the Mineralogist, and that in Industrial Geology

III Report of the State Botanist

IV Report of the State Entomologist

V Report on the Zoology section

VI Report on the Archeology section

VII Publications of the year

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I

CONDITION OF THE SCIENTIFIC COLLECTIONS CONSTITUTING THE STATE MUSEUM

Since my last report some changes have been necessitated in the location of the collections of the museum, all of which present locations are to be regarded as wholly temporary while awaiting transference to the Education Building. Some displacement from old locations has been necessary to accommodate the demands of the Commissioner of Agriculture for increased room in the Geological Hall. Giving way to these requirements has resulted in again dispersing parts of the collections of the Geological Hall into other buildings in the city of Albany and has involved the Department in serious expenditures for rental and maintenance of new quarters. An inevitable disquietude has resulted from these invasions which has been somewhat increased by the preparation necessary for final removal and instalment of all the collections and the progress of new undertakings requiring additional working room.

At the present time the collections of the State Museum are distributed as follows:

1 Geological Hall. In this building there still remain the offices of the Assistant State Geologist and his staff; of the Mineralogist, and some part of the collections in geology, paleontology and mineralogy; the seismograph is also installed here; also the offices of the State Botanist, with the botanical collections constituting the State her-

barium; of the State Entomologist with the collections pertaining thereto; of the Zoologist, with all collections in zoology except for instances otherwise specified; workrooms of the taxidermist and archeologist.

2 State Hall. The rooms occupied in this building are the offices of the Director and State Geologist with his immediate staff, together with the extensive collections in paleontology and some others of value. These collections are in drawers and in preparation for removal.

3 Capitol. The corridors of the fourth floor contain on display a very considerable collection in archeology, though only a fraction of such material as is in our custody. In these corridors also are a few cases of mineralogic, paleontologic and ceramic exhibits. On the sixth floor of this building are 100 drawers of minerals and certain large relief maps. In the safe in the Cashier's office, Education Department are the archives of the Iroquois Nation consisting of wampum belts and other articles of historical importance.

4 McCredie Malthouse. This is the general storehouse for all the collections and equipment of the museum which have been displaced by the recent invasions of the Geological Hall or for which no other place can be found. About 500 cases of specimens are here stored.

5 Universalist Church. This building, situated at the corner of Swan and Jay streets, has been rented at the expense of this division and is being utilized as a studio for the artist engaged in preparing the very large background scenery for the Iroquois collection and as office and workroom for the Archeologist.

6 State Normal College. In the corridors of one of the western buildings is temporarily placed, by courtesy of the president, a large, newly mounted group of black bears.

7 Property of J. L. Verstrepen, Delaware street, Albany. Here is a series of large geological specimens which are being removed as opportunity affords.

8 Flint Granite Company, Cemetery Station. At this place, 3 miles north of Albany, is stored a large and unique slab of trails from the Potsdam sandstone, weighing upward of 20 tons.

To this record of 8 widely separated locations in the city of Albany is to be added the fact that there are in storage and under insurance, awaiting transportation whenever accommodations here

permit, several large mounted groups of mammals (moose, buffalo and others) in charge of the Ward Natural Science Establishment at Rochester.

This much divided and scattered condition of the work is profoundly embarrassing and involves serious loss in concentration of effort and of time and enjoins arduous and exacting conditions. Yet it may be regarded as making for progress, as it certainly is now unavoidable in preparing for the equipment of a new museum.

This situation has not been allowed to interfere with the progress of the proper scientific investigations of this division, which have taken the direction indicated herewith.

II

REPORT ON THE GEOLOGICAL SURVEY, INCLUDING THE WORK OF THE STATE GEOLOGIST AND PALEONTOLOGIST, OF THE MINERALOGIST AND THAT ON INDUSTRIAL GEOLOGY

GEOLOGICAL SURVEY

Areal geology

In the progress of the survey directed toward the execution of the geological map of the State on the topographic scale of 1 mile to 1 inch, a considerable number of topographic quadrangles have been completed and published, with full explanatory details of geological structure. In addition to the completed quadrangles a variety of special maps have been issued in connection with particular geological problems, some of the older of these maps being on such geographic base of approximate accuracy as was best available, but all special maps of later years, whether they have covered limited areas, completed county areas or a series of counties, have been based on the topographic unit.

A list of all geologic maps of the State, of every description, was published in my report of last year, and the number was there shown to be large, 329 entries being recorded. I append here a list designed to indicate only the complete quadrangle maps which have been made with special reference to the systematic execution of the State map. In this list the terms starred indicate maps now in press.

*Alexandria Bay (Cushing)
Amsterdam (Prosser & Cummings)
Auburn (Luther)
Buffalo (Luther)
Canandaigua (Clarke & Luther)
*Cape Vincent (Ruedemann)
*Clayton (Cushing & Ruedemann)
*Elizabethtown (Kemp)
Elmira (Clarke & Luther)
Genoa (Luther)
*Grindstone Island (Cushing & Smyth)
Hammondsport (Luther)
Hempstead (Woodworth)
Little Falls (Cushing)
Long Lake (Cushing)
Mooers (Woodworth)
Naples (Clarke & Luther)
Nunda (Clarke & Luther)
Olean (Glenn)
Ontario Beach (Hartnagel)
Ovid (Luther)
Oyster Bay (Woodworth)
Penn Yan (Luther)
Portage (Clarke & Luther)
*Port Henry (Kemp & Ruedemann)
Port Leyden (Miller)
Remsen (Miller)
Rochester (Hartnagel)
Salamanca (Glenn)
*Theresa (Cushing & Ruedemann)
Tully (Luther)
Watkins (Clarke & Luther)

In addition to these, reports have been rendered to the Director on the quadrangles listed below, these awaiting publication chiefly for completion in certain details.

Cazenovia
Chittenango
Morrisville
Syracuse

Central and western New York. In western New York final resurvey has been made by Mr Luther of the Caledonia, Honeoye, Wayland and Phelps quadrangles and preliminary control of the Batavia, Attica and Depew quadrangles with an expansion of operations of previous years on the Albion, Medina and Lockport regions. These results represent in part the gradual summation of work extending over several seasons and the progressive attack on new fields.

In central New York the Utica quadrangle was covered in a preliminary control by Mr Clark and work on the Sangerfield quadrangle progressed by Mr Whitnall.

Eastern New York, *Saratoga county.* Saratoga Springs has, for several years, been the seat of a litigious activity in which the welfare of the mineral water and gas springs is involved, with deep concern to a variety of commercial interests. By virtue of recent legislation the State has set itself to save the mineral water springs. It is a worthy but difficult task; worthy, because the Saratoga springs present a unique geological phenomenon which should be saved from destruction, irrespective of the commercial interests involved; difficult, because the intervention of government has come late and is confronted by large vested rights.

With regard to the adjudication of important issues now in the courts and arising from the situation at Saratoga, the State Geologist can have nothing to say, but he can and desires to emphasize the fact that the relations of the mineral springs to each other and to the gas springs are a strictly geological problem. These relations must be understood before any determination of intelligent modes of reclamation can be hoped for, and should be comprehended before any readjustment of recognized rights in the properties involved is attempted. This geological problem is not an easy one. No such problem, deeply buried out of sight and reached only by the drill, is easy. There is probably no place where the subterranean conditions at Saratoga are paralleled and the obscurity of their interrelations makes the problem of the source and durability of the waters, their salinity and their pressures one of difficult reach, but the analyses can not be prosecuted by any other mode of attack than the geological.

The Saratoga springs have been a fruitful source of theories and vagaries by casual geologists, chemists, mineralogists and hydrographers, which are so frequently contradictory and have been so often exploited, as to weaken confidence in most of the solutions proposed. So often have favored contentions for and against one or another exposition of the conditions been promulgated from the witness stand and elsewhere that the present situation leaves everything to be desired in regard to exact knowledge as a basis of procedure on the part of the State, if the Saratoga springs are to be effectively protected.

With full realization of the seriousness of the problem there presented and of its difficulties, the State Geologist organized a resurvey of the Saratoga springs region during the past season. This survey was, of compulsion, confined to a review of the surface structures of the country. It was fully understood that such an undertaking, unsupported by the drill, must be inadequate in its results, for in a subterranean problem the drill is the geologist's finger. Appropriations, however, were wanting to carry on this extensive but essential part of the work. The records of the many commercial wells put down at Saratoga are lost or inaccessible, and no conclusions of the problem can be reached and no proper procedure for the conservation of the springs be deduced until redrilling over the extensive area has been carefully executed.

The field work of the season was not, however, without good results in its bearing on the problems at issue and the survey of

the Saratoga quadrangle carried on by Drs Cushing and Ruedemann will be continued and concluded by being brought into connection with the survey of the Broadalbin quadrangle by W. J. Miller.

Referring specially to the field determinations made in this work, certain stratigraphic details have been perfected.

The limestone of the Mohawk valley, which has heretofore been classed as "Beekmantown," proves to be composed of two unconformable members, the upper, comprising the so called "fucoidal beds," a limestone of lower Beekmantown age, and the name *Tribes Hill limestone* has been proposed for it; the lower is of dolomite, is older than the Beekmantown, and the name *Little Falls dolomite* is restricted to this member. The upper formation thins westward and disappears just west of Little Falls.

In the eastern part of the Mohawk valley the Potsdam sandstone appears beneath the Little Falls dolomite, grading up into it through a series of passage beds, the two plainly belonging to the same formation. At Saratoga the basal portion of the Little Falls dolomite becomes locally a fossiliferous limestone, which has been provisionally termed the *Hoyt limestone.* Over it the Little Falls dolomite, but the true Beekmantown seems to be absent, the Trenton limestone resting on the Little Falls dolomite. Traced through Whitehall to Ticonderoga the latter is found to be directly equivalent to Division A of the Beekmantown division which lies unconformably beneath the remainder of the Beekmantown and does not belong with it but with the Potsdam and passage beds between.

On the Broadalbin quadrangle in Fulton and Saratoga counties, the area comprises rocks of Precambric, Paleozoic and Pleistocene ages.

The Precambric rocks cover about one third of the quadrangle and are chiefly represented by the Grenville schists with which are associated younger foliated syenite and porphyritic granite as well as nonfoliated dikes of gabbro or diabase. The remainder of the area is occupied by Paleozoic formations including the Potsdam, Little Falls, Trenton, Utica and Lorraine formations.

Of the Precambric rocks the Grenville, in several distinct areas, is by far the most common, one area alone occupying more than 40 square miles. Belts of very pure quartzite are at times found in the Grenville. The syenite and granite are highly

metamorphosed, the syenite commonly appearing almost schistose.

The true Beekmantown appears to be absent from the Broadalbin quadrangle so that the Trenton always rests unconformably upon the Little Falls dolomite. A series of distinctly transitional beds lies between the Potsdam sandstone and the Little Falls dolomite. This formation has been named from the town of Galway where it is best shown and it has been separately shown on the geologic map. Toward the southeast the Potsdam has at its base a very interesting conglomerate made up of Grenville quartzite fragments from 1 to 3 feet in diameter.

The district is remarkable for its faults, no less than 14 having been mapped. They are all normal with displacements ranging from 100 to 150 feet. Several of these have been mapped for the first time, and one of these, the *Batchellerville fault,* showing a displacement of 1500 feet, has been traced for over 10 miles. The Batchellerville fault is also of interest because, so far as known, it is the greatest of the Mohawk valley faults with the upthrow side on the east.

Pleistocene deposits of various types are finely exhibited. There is distinct evidence, as shown by A. P. Brigham, that a current of ice flowing south-southwestward past Northville met another current flowing northwestward past Galway in the vicinity of Broadalbin. The lowest land, including the area of the great swamp known as the "Vly," was once covered by a glacial lake.

Adirondacks. Last year I reported the completion of the survey of the Elizabethtown and Port Henry quadrangles by Professor Kemp and Dr Ruedemann and this report is now in press. Professor Kemp has followed this by the survey of the Mt Marcy quadrangle which lies next west. The field work had been done upon the area in former years and the final report had been to some degree blocked out.

This section of the Adirondacks contains many points of special interest. The two summits, Mt Marcy and Mt McIntyre, which alone of all the peaks exceed 5000 feet, are within it. Of the 16 peaks which stand between 4000 and 5000 feet, 14 are also here. The remaining two are Giant, which lies just east, and Whiteface which is a few miles north. It will thus be readily seen that we are here dealing with the culmination of the Adirondacks.

Careful study of the mountains brings out the fact that in the

large way the ridges trend northeast and southwest, yet this general structural feature is modified by two broad north and south valleys, of which the larger, the famous "Keene valley," contains the chief settlements and the smaller is marked by Elk lake. These latter valleys are believed to be old topographic depressions which have antedated the northeast and southwest faults, the causes of the later ridges.

The northwestern portion of the quadrangle is occupied by a great gravel flat standing at approximately the 2000 foot contour and much cut up by the streams. Over at least 10 square miles of area, no bed rock exposure is visible and one is forced to conclude that some relatively wide and open valley has been buried by the gravels which were incidental to the waning glacial period.

The postglacial deposits and the moraines of the ice period itself have done much to modify the relief and rearrange the drainage. There is good evidence of a lake that must have been impounded by some barrier on the north and that filled the Keene valley during the closing of the glacial period. The gravelly deltas along the sides of the valley admit of no other interpretation and in the case of the terrace on which the Willey House stands just beyond the northeast corner of the quadrangle, the amount of gravel is so great as to be very impressive.

There is little doubt that in the preglacial times the area around the Upper Ausable lake drained off to the southwest through the Boreas river and that drift has changed the old order of things. The present divide is in a swampy area and is scarcely 20 feet high.

There are many precipitous mountain fronts which usually trend northeast and southwest and afford beautiful scenery. In the narrow passes at their feet lakes may be situated, such as the Cascade lakes, the Lower Ausable, and Avalanche. Some of the mountains are also sharp and narrow in their summits, as in the case of the Gothics. Others, like Marcy, are rounded and dome-shaped.

The hard rock geology is similar to other Adirondack quadrangles, already described in the bulletins of the State Museum. The oldest rocks are the Grenville sediments which are well shown in the Keene valley. Except for one small patch, apparently caught up in the anorthosites just south of the Cascade lakes, they do not appear outside this depression. They may, however, lie buried beneath the gravels of North Elba and also of the Elk Lake basin.

The rocks next in age are the anorthosites, which cover almost all the quadrangle. They are its characteristic rock and constitute all the high peaks but one. The blue labradorite rock, sometimes giving opalescent colors in the brooks, is almost universal. The syenite series enters from the north and in a variety that is transitional to the anorthosites constitutes Pitchoff mountain. The syenites soon fail, however, and the anorthosites take their place.

The anorthosites are cut by a number of intrusive masses of basic gabbro, of which the wonderful dike at Avalanche lake is a striking example. It runs from the lake to the summit of the ridge, cleaving two mountains apart like a wedge.

There are numerous basaltic dikes which favor the northeasterly fault cracks.

The intrusive anorthosites have wrought some contact effects upon the old Grenville limestones which are among the best illustrations of these phenomena yet noted in the Adirondacks. The limestones have been changed in one locality to masses of red garnet and green pyroxene, and in another have a body of magnetite much mixed up with garnet and other contact minerals. The ore body was mined to some extent in the old days of the forges but is now idle. It is the only ore deposit worthy of mention yet found in the quadrangle. The great predominance of the anorthosites would lead us to anticipate only titaniferous ores outside of the Grenville area.

Mineral wealth is thus lacking. The entertainment of summer visitors and the lumber business are the chief means of support of the inhabitants.

Southeastern New York. In my report of last year reference was made to *cooperative undertakings with the New York City Board of Water Supply,* with reference to the assembling of the geological data recorded in that great engineering enterprise. During the year past, Dr Berkey has brought together from these sources and from independent surveys of the contiguous territory, begun before this form of cooperation was effected, the general summary of new knowledge in the form of a bulletin which has been submitted for publication. In the preparation of this bulletin the immediate object has been to place in convenient form an outline of the present understanding of the geology of the region and to discuss facts gathered in this extensive exploratory work carried on along the course of the Catskill aqueduct, with special reference to the geological structures on Man-

hattan island. The task has proven a difficult one. It has been found necessary to summarize the data and give results rather than to present the whole mass of facts. The final outcome will be the solution of a series of problems very largely in the form they have presented themselves to the practical engineer and others working on them. The bulletin therefore falls readily into the line of applied geology and it is believed will have distinctive educational use in that field.

Detailed study of old drill borings in New York city has led to the opinion that the present conception of the areal and structural geology of Manhattan island and the East river needs considerable correction. This, however, applies only to the southern portion under heavy drift cover. The tunnel developments of the city make details of this sort of much importance. Instead of the island being wholly Manhattan schist, the data seemed to require that at least two narrow belts of the Inwood limestone and Fordham gneiss should extend through the lower east side. Explorations designed to test this theory have proven it to be true. Limestone does not follow the East river continuously. A large area of grano-diorite cuts through the gneisses in Long Island City and Brooklyn and crosses the East river into Manhattan. A corrected map of this section will be published in the bulletin.

The exceptional advantages offered by tunnels now being constructed throughout the Highlands region along the aqueduct makes it possible to see the prominence of some structural features that are otherwise obscure. Faults and crush zones and other effects of movement are surprisingly numerous. They are in all stages between complete recementation and complete decay. Some of the older are in as good physical condition as the original wall rock, others of later origin are reduced to clay or similar incoherent matter to great depth. In at least one such case on Manhattan island, complete decay extends to a depth of over 300 feet.

Additional exploration on the Hudson river indicates clearly that there has been glacial widening of the preglacial gorge at the Storm King entrance to the Highlands and that there is probably also glacial overdeepening. Borings in the channel have penetrated silts, sands and drift to a depth of – 674 feet at which point it is now believed rock bottom has been encountered.

Further detailed field observations tend to confirm the opinion previously given that metamorphosed sediments constitute the most ancient rock types of this region and that they are the equivalents of the Grenville series as known in the Adirondacks.

Work on the *Poughkeepsie quadrangle* has been carried forward by Prof. C. H. Gordon, who reports as follows:

Precambric. Some portions of the gneissic areas were reviewed with care. It has seemed entirely possible to establish the identity of the rocks which make up the narrow strip that extends from the carpet mills at Wolcottville northeastward to Vly mountain with the gneisses of the Fishkill mountains. This strip, which will be referred to as the Glenham belt, was described by Mather as the "Matteawan granite."

The rocks which make up its major portion vary from greenish granitic types of rather massive character to more gneissoid and usually somewhat finer grained rocks with reddish color. The primary minerals composing these two varieties are quite similar and are quartz, microcline or orthoclase, plagioclase and biotite. The last named has undergone alteration which appears to be an ancient character. During the period of this alteration the biotite was more or less completely changed to chlorite and considerable quantities of iron oxids were liberated. Occasionally the granitic rock passes into a type with scarcely any ferromagnesian minerals, with milky quartz and a feldspar pink from disseminated iron particles. These varieties grade into one another although the greenish rock is most abundant in the southern end of the strip and the gneissoid type around Vly mountain. The varieties just described are those which have been emphasized by most observers and have been called "altered sandstone," "bastard granite," etc.

Within the last two or three years new cuts have been opened in this strip in the process of evening up the grade on the road from Fishkill village to Wappinger Falls. This road cuts the strip about midway of its length. Among the rock varieties exposed in these cuts are hornblende and micaceous gneisses quite similar to some of those seen in the Fishkill mountains and several varieties of altered gneissic derivatives. Epidote is abundant in many outcrops.

It has proved possible to trace in a satisfactory manner the rocks composing this strip through somewhat similar masses lying at the south in Matteawan to the base of the Fishkill mountains. Rocks identical with the altered and epidotic gneisses

and greenish and gneissoid rocks of this strip were found in the eastern part of the town of Matteawan. Certain easily marked faults have broken the areal continuity of the whole.

The Glenham belt near Vly mountain shows a small patch of the quartzite. In Matteawan a considerable knoll of the basal quartzite is preserved between Anderson, Grove and Walcott streets near "Rock hollow." The Precambric age of these masses is thus indicated. The Glenham belt and the smaller masses at the south are interpreted as inliers of the older rocks. The Glenham belt is a faulted inlier. The others are probably such. The rocks which make up the larger part of these inliers are looked upon as altered derivatives of the gneisses. They belong to the same general epoch as the quartzite, that of the transgressing Cambric sea. Their present compact condition is due to the same metamorphic processes that changed the basal sandstone to a quartzite and the overlying limestones and slate to their present condition.

At Hortontown, a small hamlet in the Highlands south of Shenandoah, a basic eruptive made up chiefly of hornblende and magnetite, with some pyroxene, is in close association with a quartzite, entirely similar to the basal quartzite and of considerable extent, and with a few scattered ledges of an altered rock made up of magnetite and bastite. The relations are very obscure. The presence of a clear fault along the eastern base of Shenandoah mountain seems to permit the interpretation that the eruptive is of Postcambric age and that it has penetrated the basal Paleozoics and altered the ferruginous dolomite without materially affecting the refractory quartzite. Most of the altered limestone has been removed.

Cambric. The discovery of the opercula of Hyolithellus micans Billings in the bluish gray limestones overlying the basal quartzite at the base of the Fishkill mountains during the previous years, indicated that fossils in the quartzite would probably be found in the neighborhood, and a slab of compact quartzite with the surfaces covered with brachiopod and trilobite fragments has been found in the yard of Ward Ladue in the West Fishkill Hook district south of Johnsville. This find led to a persistent search for the quartzite in place. A few weeks later the fossils were found about ½ mile to the south. The locality may be reached by taking the east road into the mountain from the West Hook, passing the house of Ward Ladue as far as Herman Adams's

house, and then by following the gully east of the road for two or three hundred yards. The ledge occurs on the east of the gully about 3 or 4 feet below the base of a stone wall that separates the gully from an old orchard on the east. The fossils occur in the hard compact quartzite similar to that in Ladue's yard, but are most numerous in the thinner, somewhat friable rusty layers just beneath. The compact rock shows dull imperfect surface markings and numerous rusty spots when broken. The friable layers show great numbers of fragments including brachiopods resembling Obolella and the spines and cheeks of trilobites identified as Olenellus sp.?).

The basal quartzite passes conformably into a bluish gray fossiliferous limestone in the orchard of Ward Ladue and north of here on the farm of William L. Ladue the limestone grades upward into calcareous shale thus giving a conformable series of Lower Cambric strata. Just what the relation of the limestone further north is to this series, it is very difficult to determine. The Lower Cambric is probably faulted up into younger limestones.

Wappinger limestone. This formation occurs within the quadrangle in two well defined masses: the composite Wappinger creek belt and the Fishkill limestone.

A portion of the former was reexamined during the past summer for the purpose of learning more about the cherty dolomitic limestone overlying the arenaceous beds carrying Lingulepsis cf. pinniformis in the western strip of this composite belt. Apparently the latter beds grade up into the dolomitic rock. The latter does not appear to bear much resemblance to the so called "Calciferous" of the central strip of this belt as developed at the type locality at Rochdale. Passing westward along the Spackenkill road from the Albany postroad one crosses the gently inclined or horizontal Upper Cambric beds at points near Ruppert's farmhouse and just a little east of this place, and then over very different cherty strata without fossils in which the stratification and dip are not distinct. The two, however, appear to be in conformity. Near Camelot station the arenaceous Potsdam beds appear pitching to the southward and south of here at the Clinton Point Stone Company's quarry at Stoneco are strata very similar to the cherty beds just described, with westward dip and such general position as to indicate that if continued northward they would have a position with reference to the Upper Cambric like that

occupied by the cherty beds along the Spackenkill road. The thick masses in the Stoneco quarry have not yielded fossils. It seems that within this western strip there is a considerable thickness of heavy dolomitic limestones lying above the Upper Cambric fossiliferous beds which are older than the Beekmantown ("Calciferous," Rochdale group). Whether this mass belongs with the Cambric of the Canadian group could not be determined, nor the question of whether deposition was continuous from one period to the other.

During the seasons of 1908 and 1909 a number of new cuts were opened in the Fishkill limestone in the process of constructing the State road from Fishkill Landing to Beekman. These were examined with considerable care, but except for one or two doubtful cases, no fossils were discovered. A mile west of East Fishkill ("Gayhead") a slightly distorted impression with form suggesting some member of the Strophomenidae was found on the freshly broken rock. All shell characters were absent, although the form was reasonably distinct.

Fossils which could be recognized have been discovered in this limestone along its western margin, in the Lower Cambric horizon, as above described, and in one instance along its northern margin near Hopewell. Elsewhere they have not been found either on fresh surfaces or in weathered outcrops.

The slate formation is almost completely eroded from this limestone mass. There is reason for thinking that much of the limestone is older than the Trenton and perhaps of Cambric or early Ordovicic age.

Hudson River slate formation. A careful examination of many outcrops in this formation has added only one new fossil locality. This occurs at a hamlet known as Swartoutville, about 2½ miles north of Brinckerhoff. The fossiliferous ledges were discovered while tracing the limestone boundary. On the farm of Irving Hitchcock at Swartoutville, about three or four hundred yards west of the road from Brinckerhoff to Hopewell Junction, is a high knoll made up of gray limy shales with interbedded limestones. The shales contain Plectambonites sericeus and other fossil fragments. These beds are regarded as lying near the base of the slate formation and as of probable Trenton age. The beds appear structurally to belong with the limestone which is faulted against the presumably younger slates on the west.

Considerable interest attaches to the discovery of several small, usually conglomeratic, limestone patches within this formation. Three of these occur near Arthursburg north of

Hopewell Junction and three somewhat larger ones east of Pleasant Valley. All appear to be brought up by faults within the slates. Several are marked by a limestone conglomerate entirely similar to the Trenton conglomerate of the Wappinger creek belt and Solenopora compacta was noted in the most western masses. These patches are now exposed because of greater thrust at the points where they now lie along extensive thrust lines. The conglomerate is often overlain by a silicious lime-sand rock which is followed by the slate formation. As far as it goes the evidence would appear to show that at the east the lime-mud rock with fossils shown at Pleasant Valley, Rochdale and at Sleight's farm near Manchester Bridge gives way to this coarser silicious sand rock. Close folding and probable thrusting have brought these two phases of contemporaneous deposition into closer areal relations than they had originally.

It seems likely that the epoch of limestone formation during the Trenton transgression within this quadrangle was of short duration. Much of the slate is probably of Trenton age.

Surficial geology

Some reference has already been made to these features in Saratoga county and additional work was done on the general field of the lower Mohawk valley region over the Broadalbin, Gloversville, Amsterdam and Fonda quadrangles by Professor Brigham. This continued field work has brought to an essential completion the classification and distribution of the surface deposits in this region and the necessary maps and report have been rendered. Extension of this survey was carried into the area north of Gloversville, a district belonging to the southern Adirondack forest and lying in the towns of Mayfield, Bleecker and Garoga in Fulton county, and including the southern parts of Benson and Arietta in Herkimer county.

The region is rugged, in large part wooded and attains a maximum altitude in Pinnacle mountain, of 2514 feet. Many other elevations approximate this altitude. The valleys and slopes are covered with a massive and fairly constant mantle of glacial drift. Rock outcrops are frequent, but the average thickness of the drift is large. Distinctly morainic accumulations are, however, not important though some low hills of this nature occur about Bleecker, Bleecker Center and Lindsley Corners. Lakes and ponds are numerous, and belong in the main to the glacial blockade type, though it would often be hazardous to affirm that glacial erosion did not enter as a component factor.

The chief interest from the point of view of the glacial geology is in the direction of the striae, records of this nature being found in about 24 localities. It is known that the movement a few miles to the south, about Gloversville and Johnstown, was westward, while the latest movement on the east, or about Northville, was southward. The average movement in the district now studied proved to be southwest, showing that the higher grounds, well into the southern Adirondacks, felt the influence of the great westward movement up the Mohawk valley. The direct southward flow at Northville seems to have been late and in the control of the local trend of the Sacandaga valley. The top of the Pinnacle, on account of weathering, does not show distinct gravings, but the molding shows clearly a southwest trend. One mile north of Rockwood, on the edge of the Lassellsville quadrangle, the striae even show a direction of w. 20°–25° n. So at Wheelerville, near Canada lake, and by Middle Stink lake, also on the Lassellsville area, readings are approximately west. Aqueo-glacial drift was very nearly absent, the chief exception being in some interesting glacial terraces about Bleecker Center.

The further extension of these Mohawk glacial waters was studied in a broad way by Professor Fairchild from Taberg in the Ontario basin to Coxsackie in the Hudson valley. The work was partly in review of critical localities and partly new mapping of the glacio-lacustrine features.

It was found that a series of glacial stream channels lie along the west side of the Hudson valley, in continuation of the stream flow across the northeast face of the Helderberg scarp.

Special problems

Clinton formation. The value of this term in the geological nomenclature of America has been a matter of some general interest and discussion and as the term is an historic one, based on a rock section at and near the village of Clinton, the significance of the name and its proper definition may be briefly referred to. It would be a matter of slender and local importance if this rock series and the fauna it contains were confined to the State of New York, but as the division was early established by the New York geologists and the formation extends very widely beyond the boundaries of the State, northeast, southwest along the Appalachians, and broadly through the west and northwest, its definition assumes an importance of some magnitude.

The Clinton formation was first called, by Vanuxem, the Protean group, on account of the variable character of its sediments and their colors. When, soon after, the geographic term *Clinton* was substituted for the formation, it was based on the rock section referred to at Clinton village, its lower limit being recognized as bounded by the Medina sandstone there present, but its upper limit being undefined, or in other words, the entire section there exposed above the Medina formation being left as the exponent of the Clinton formation. In the Genesee valley the Clinton term was also recognized and used contemporaneously by Hall. There the formation is much more advantageously and completely expressed, and over it lies without interruption a bed of gray shale which was separately designated by Hall as the *Rochester shale.*

Our knowledge of the fauna of the Clinton unit, as well as of the Rochester shale, has been essentially derived from the Genesee section. With the progress of knowledge it is satisfactorily determined that at the Clinton section at Clinton is a weak development of the Rochester shale and this was included by inference in Vanuxem's definition of the Clinton formation.

In actual date of establishment the term Rochester shale is older than Clinton, but only the work of later years has shown the presence of the earlier named formation in the "type" section of the latter. The question has, from these acknowledged conditions, arisen in this form: Shall the Clinton formation be made to include the deposits and fauna of the Rochester shale?

In New York we have felt disposed to hold the view that the early geologists, of course totally unaware of the sharp and precise requirements of an advanced knowledge, employed formational terms with some degree of elasticity, even of laxity, and in the particular case in hand, that the rock succession in the Genesee valley is a truer demonstration of actual relationships and its early denominations a more faithful expression of successive geological events than either section or names in the Clinton section. It seems to us doubtful whether ancient and loosely defined names can wisely be resuscitated, in defiance of advances in knowledge, or whether such attempts at resuscitation are not virtually new definitions, thus lacking wholly the merit claimed for their age.

The stratigraphic contrast in these two sections is very pronounced. In the Rochester or Genesee river section the Clinton

beds from below are as follows: (1) Sodus shale, (2) Furnaceville ore, (3) Wolcott limestone, (4) Williamson shale, (5) Irondequoit limestone. In the Clinton section no entirely satisfactory division of the strata has yet been made. How far the divisions of the Rochester section can be correlated with or applied to the Clinton section is still to be determined, but they now seem to have little in common. The Wolcott limestone is certainly not repeated in the section at Clinton, and the presence and extent of the other divisions can be determined only by careful study of the intervening area.

At Clinton there is an important stratigraphic and faunal break at the top of the green shale overlying the lower or oolitic ore bed. The shale is here overlain by heavy limestones showing traces of ore and 9 feet higher is the upper ore or red flux bed.

The fauna of this section indicates the presence of species of the Rochester member well down in the strata and in paleontology it may be unwise to separate the Rochester member and its fauna from the series with which it is so intimately bound in this typical section. To expand the group value of the term *Clinton* by the addition of the member Rochester involves a subtraction from the Niagaran group in like degree. This procedure may be necessary however as it is evident that final resolution of the original Clinton will leave no element that can serve as a Clinton member, except perhaps the ore beds which have long held wide recognition in the Appalachian region as the *Clinton iron ores.*

Dikes near Clintonville, Onondaga co. Dr Burnett Smith of the geological department of Syracuse University has recorded in *Science* (Nov. 19, 1909) his recent discovery of heretofore unknown igneous dikes in the sedimentary rocks of Onondaga county. Dr Smith's notice follows:

The presence of a few igneous intrusions in the almost undisturbed Paleozoic strata of central New York has long been known to geologists. Their extreme rarity, however, has always invested them with a peculiar interest.

Excluding the Manheim dike near Little Falls, which lies about 75 miles east of Syracuse and which cuts Ordovician strata, we find that these igneous rocks may be grouped geographically into (1) those occurring in the vicinity of Ithaca and Ludlowville and (2) those occurring in the vicinity of Syracuse. In both regions the intrusions are peridotite and are mostly true dikes cutting in the first case such Upper Devonian formations as the Genesee shale and the Portage and Ithaca shales and sandstones, and in the second case cutting the Salina beds of Silurian age.

As far as the writer has been able to learn, the geologically intermediate Hamilton shale has, until now, yielded no dikes and the recent discovery of two in this formation at a locality about 12 miles southwest of Syracuse and about 40 miles northeasterly from Ithaca is believed to be a matter of interest.

The dikes in question are exposed on the south wall of the Clintonville ravine at a point approximately 50 feet above the level of the Marietta road. The more western is a fine grained porphyritic rock resembling peridotite. What appear to be serpentine grains, produced by the alteration of olivin, protrude from the weathered surface and have the appearance of small pebbles. Another conspicuous feature is furnished by large scales of a bronzy mica. This dike has a uniform width of from 7 to 8 inches and is displayed for about 12 feet on the south bank of the ravine. On the north side it is obscured by talus. Its plane is vertical, while its direction is north and south, agreeing in this latter respect with the Ithaca dikes. Wherever examined it presents a very uniform texture, is apparently free from fragments of the sedimentary rocks through which it passed, and has produced little contact metamorphism.

The second dike discovered by the writer lies about 2 feet and 4 inches to the east of the first and was not observed until the wall at this point had been cleaned. It has a width of about 8 inches. Like the first dike, it is vertical and north and south in direction. It differs, however, from the first dike in being much weathered in places and in containing many shale fragments some of which have a long diameter of 3 inches or more.

Dr Smith has, at my request, supplied specimens from these interesting occurrences for examination by Prof. C. H. Smyth jr, whose acquaintance with the other dikes on the sedimentaries of central New York is intimate, and the latter has supplied some notes thereupon, essentially as follows:

They are greatly altered alnoites. The olivin is completely broken down into serpentine, magnetite and, often, carbonates. At the same time, the mica remains surprisingly fresh, as it does in other dikes of the region. Perofskite, so abundant in the Manheim dike, is much less conspicuous here, while the critical mineral, so far as classification is concerned, melilite, is almost obliterated. One section from each dike, however, shows what I consider quite unmistakable traces of melilite, in one case a good deal of it, and I have no doubt that if the material were entirely fresh, the rock would prove to be quite typical alnoite.

At first glance, it may appear that the presence or absence of melilite is a trifling matter, since, at most, it probably would be only a minor constituent, the rock consisting chiefly of olivin and mica, and thus, for the most part, resembling, if not belonging to, the peridotites. But, really, the question is of more than ordinary interest, for as soon as melilite appears in an olivin rock

of this type, we are dealing with a rare variety, which is rarely found except in association with nepheline-syenite.

From this it follows that the presence or absence of melilite, instead of being a mere matter of one mineral more or less in the rock, determines the latter as belonging in the alkaline or subalkaline group, as the case may be, the peridotites belonging in the latter class, the alnoites in the former. Now as this distinction, recognized by Iddings nearly 20 years ago, and recently emphasized by Harker, is probably the most fundamental and far-reaching subdivision of igneous rocks that we have, it is, of course, a vital matter in the history of these dikes to determine in which group they belong, and the whole matter turns upon the one mineral — melilite. If the rocks contain melilite, they are alnoites and in the alkaline, or, to use Harker's term, Atlantic group. On the other hand, if they contain no melilite, they are peridotites and belong to the subalkaline or Pacific group. As these groups are not only of the first order of magnitude, but, as shown by Harker, may be genetically connected with major types of crustal movement, there is a heavy responsibility resting upon this one regrettably unstable mineral.

Rock cities of Cattaraugus county. It is not generally known that these singularly picturesque exhibits of rock decay are entirely unique among the scenic features of this State. New York is well supplied with striking scenic effects resulting from the more usual procedures of natural forces; cataracts and erosion gorges, ravines and chasms, mountains of grandeur and stockaded cliffs; natural rock bridges and subterranean caverns. These rock cities, however, particularly that situated a few miles south of Olean, Cattaraugus co., are phenomena of another order, wherein the decomposition of the rock beds under meteoric agencies has broken and gashed the rock beds into extraordinary picturesque effects. Their unusual features attracted the special attention of the geologists at the time of the original survey, 1836–42, and Professor Hall made an extended reference to them, accompanied by a series of effective sketches drawn by Prof. Eben N. Hosford, then his field assistant.

These rock cities are situated high on the summits of the hills and in the days of the pioneer survey were accessible only with difficulty. The growth of population and facilities of intercourse have now brought the most striking of these, that near Olean, into easy reach of the public, by means of a trolley system running thence to Bradford, Pa. over a route of rare picturesqueness. The Olean rock city is happily under control and protection from the encroachments of timber cutting and oil drilling which had begun to attack it.

Sketch of the northern edge of the conglomerate, 6 miles south of Olean, in Allegany county. From a sketch by Prof. E. N. Horsford, published in the Geological Report of the Fourth District, 1843

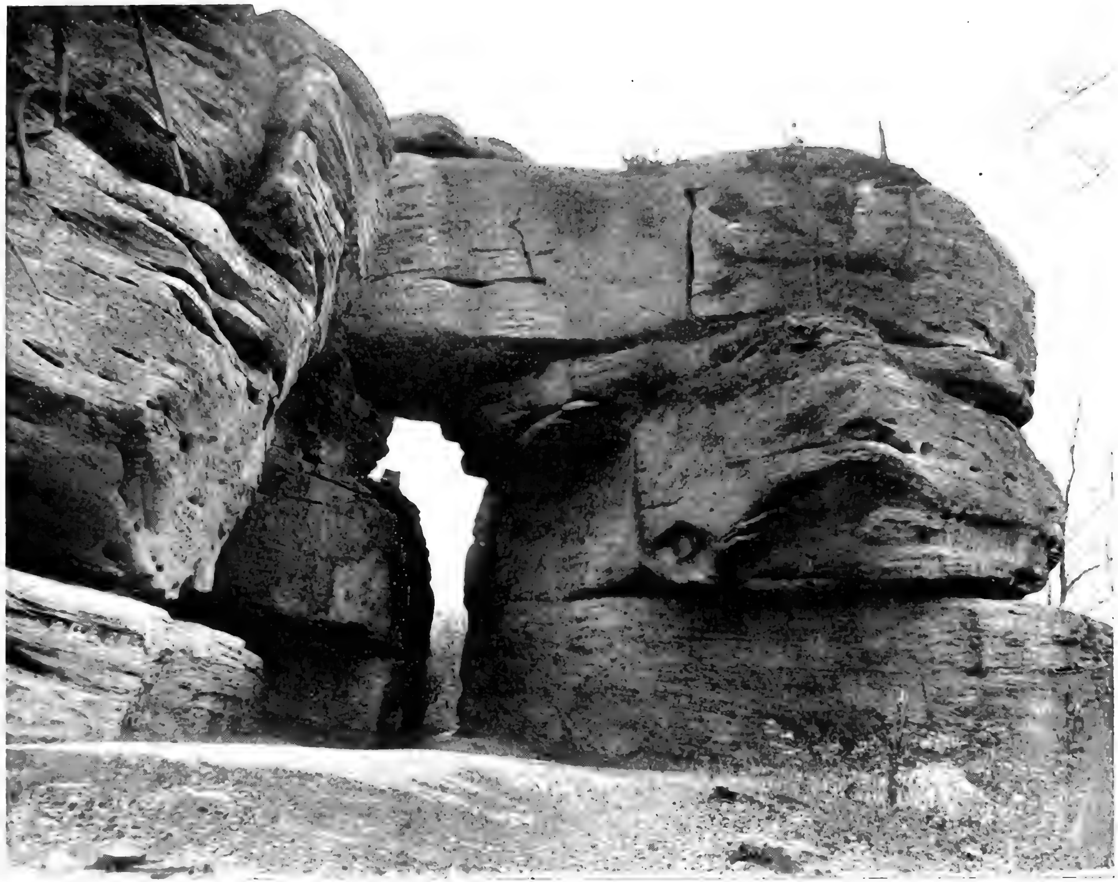
Plate 1

Olean Rock city. Top of the conglomerate with joint crevices

Plate 2

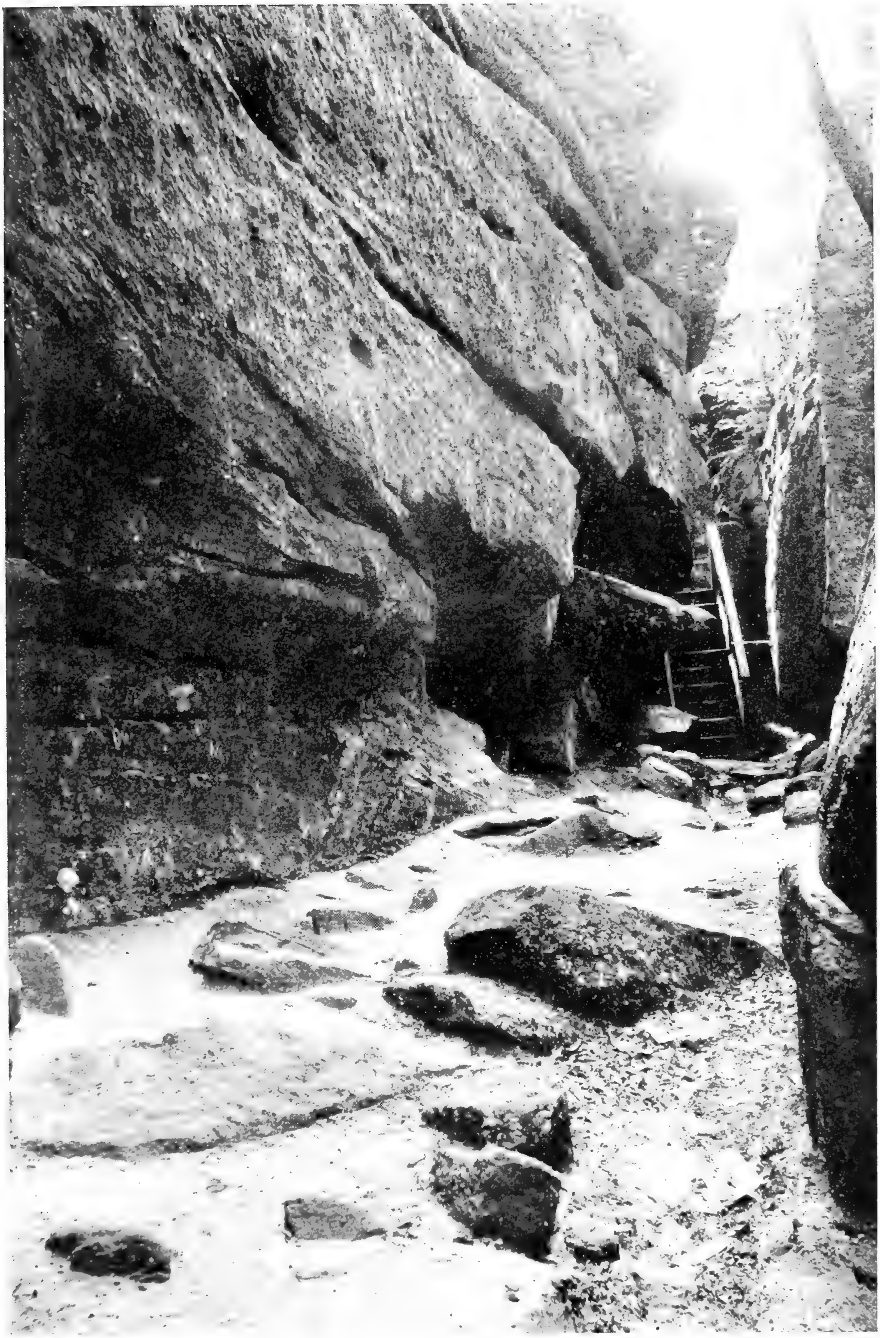
Olean Rock city. Surface of the white quartz pebble conglomerate

Plate 3



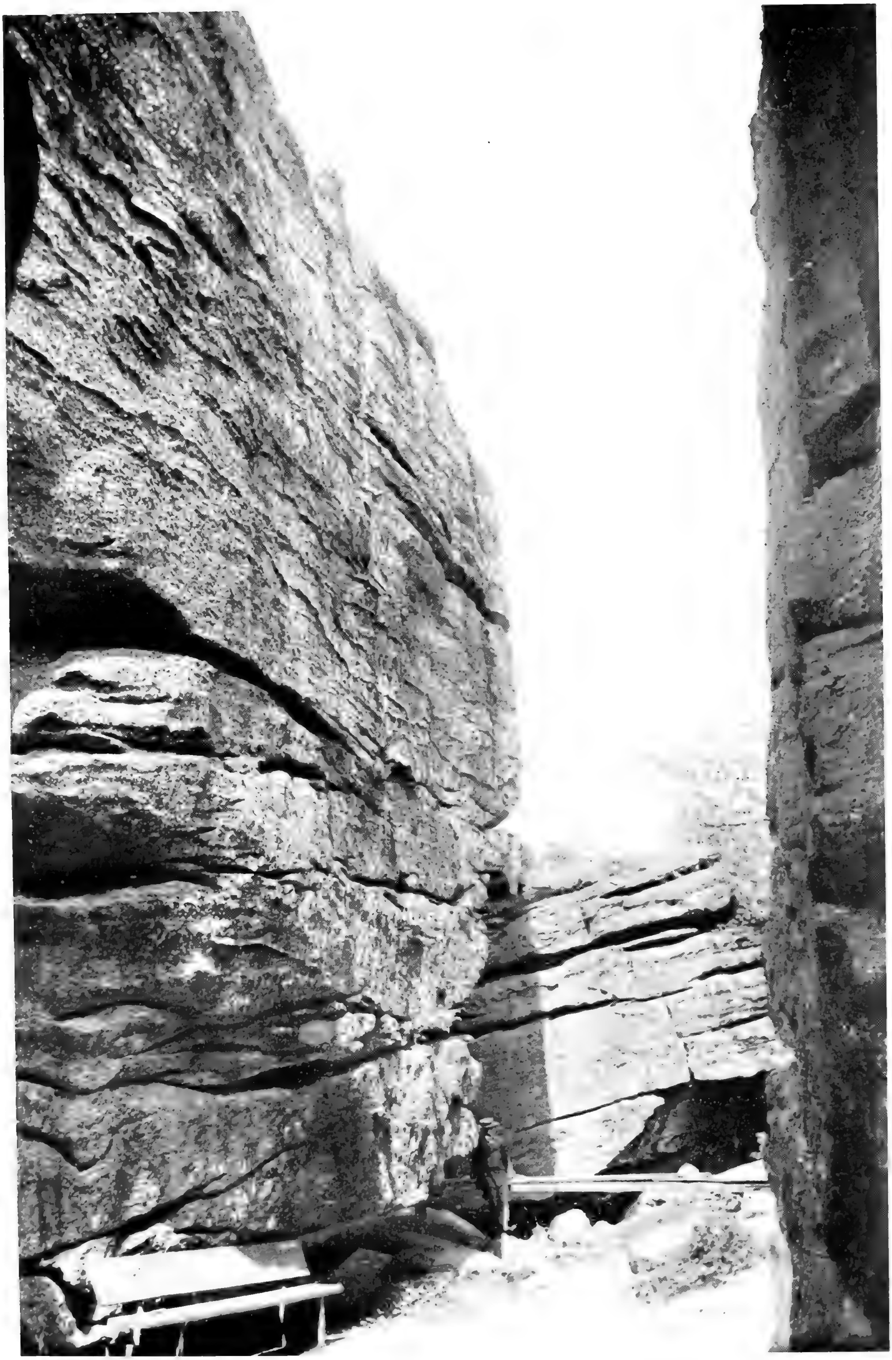
Olean Rock city. "The Arch"

Plate 4



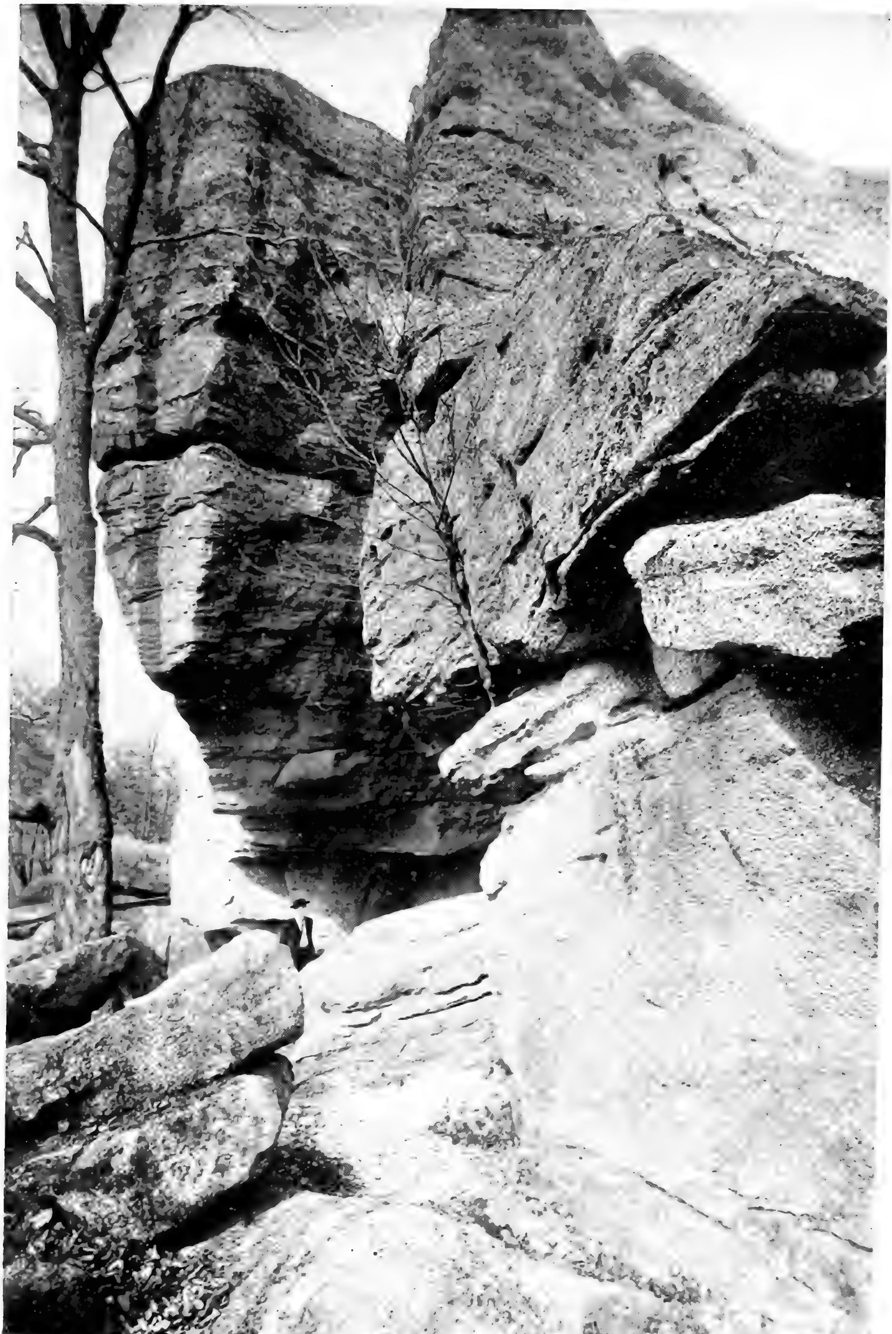
Olean Rock city. The bottom of a joint crevice due to decay

Plate 5



Olean Rock city. Weathered crevice in the conglomerate

Plate 6

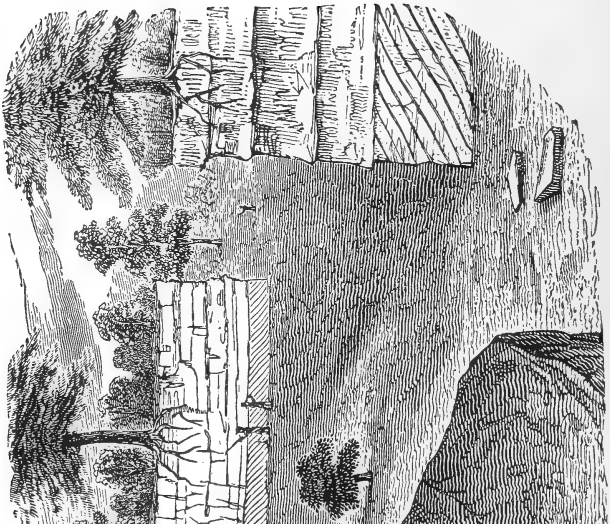


Olean Rock city. The jointed conglomerate partly undermined by decay

These rock cities consist of immense quadratic blocks of conglomerate (Olean conglomerate of the geological series) which form the capstone of the broken plateau whereon they rest. The Olean rock city lies at 2400 feet above tide and is highest of them all. The procedure of erosion in cutting out the bounding valleys of these hills has left only remnants of this sheet of white quartz conglomerate, now broken up into giant parallelopipeda by the slow action of atmospheric agencies working along original lines of structure. These structural lines are the vertical series of joint faces produced by shrinkage in and lateral strains upon the rock beds. The Olean conglomerate which composes the Olean rock city, is represented here in very nearly its entire thickness in this State and although for a large part a conglomerate of rounded milk-white quartz pebbles, yet the intervening bands of deposits are fine quartz sand.

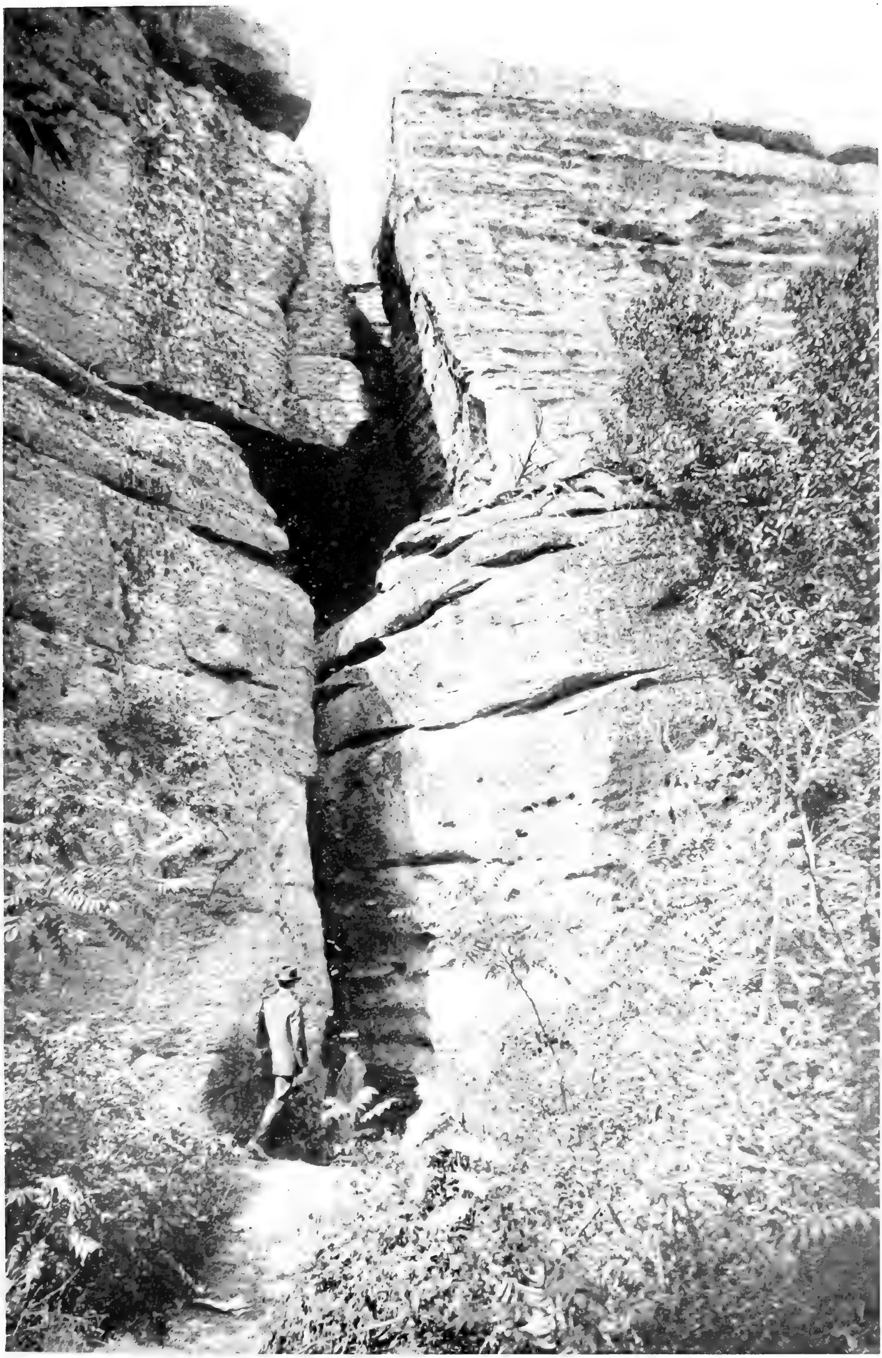
There is nothing above this conglomerate except a few feet of sandy shale which are now embraced within the same geological unit. This Olean conglomerate not only forms the capstone of these southern hills, but also the capstone of the New York series of geological formations, it being the highest and latest term in the Carbonic rocks of the State, corresponding in part to the Pottsville division of the Pennsylvania coal measure series.

The easy decomposition of this rock is due to the fact of its singular weakness of cementation. The pebbles and sand grains are held together, not by any calcareous binder, but by a faint and tenuous deposit of silica derived from the solution and redeposition of the quartz pebbles themselves. So feebly are both conglomerate and sandstones bound that an easy blow, often no more than a hand pressure, will separate a fragment. It would appear therefore that time has still been wanting for a firm cementation by redeposition of a secondary silica,



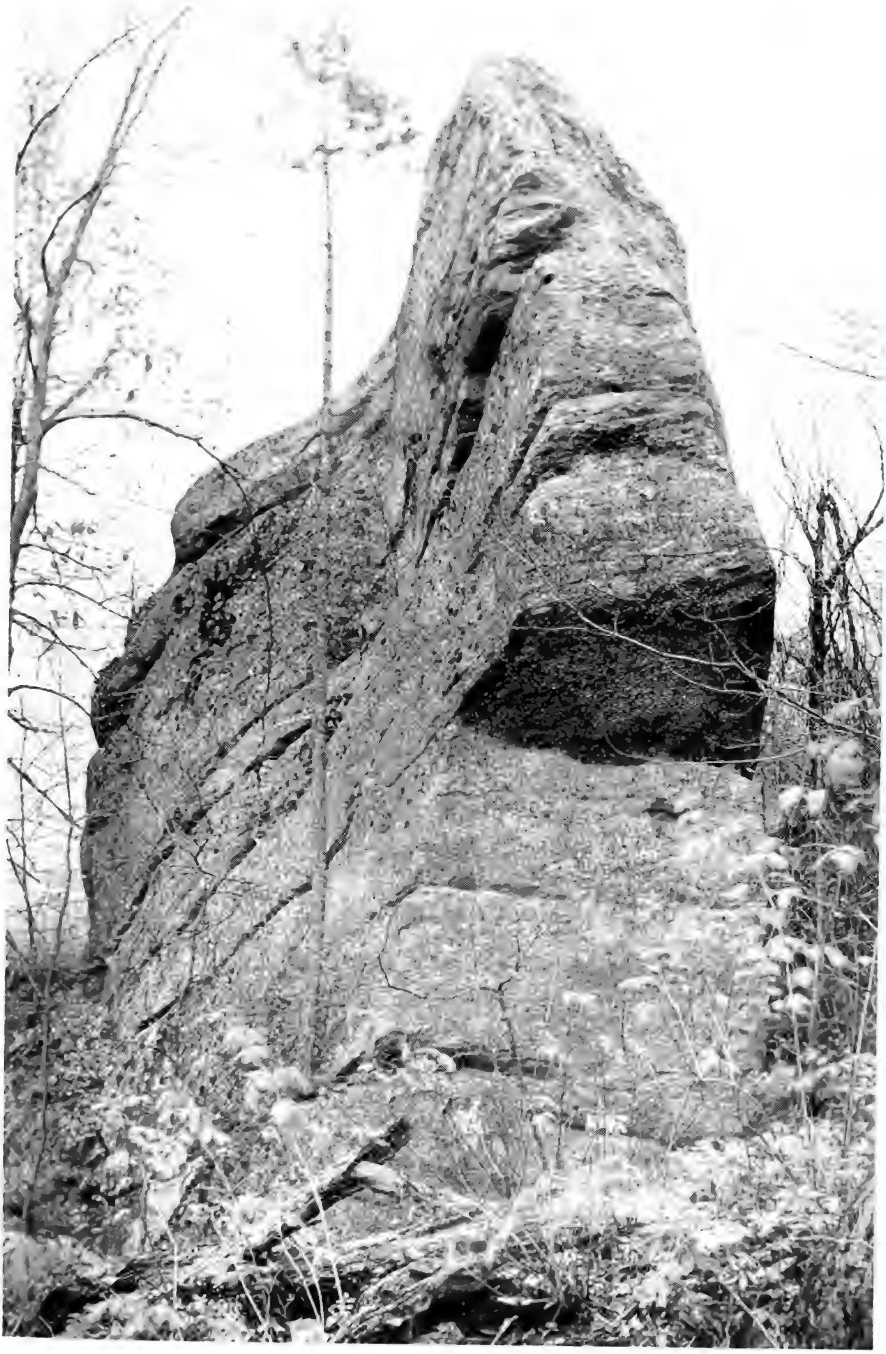
View in Rock City, 7 miles south of Ellicottville. From a sketch by Prof. E. N. Horsford, published in the Geological Report of the Fourth District, 1843

Plate 7



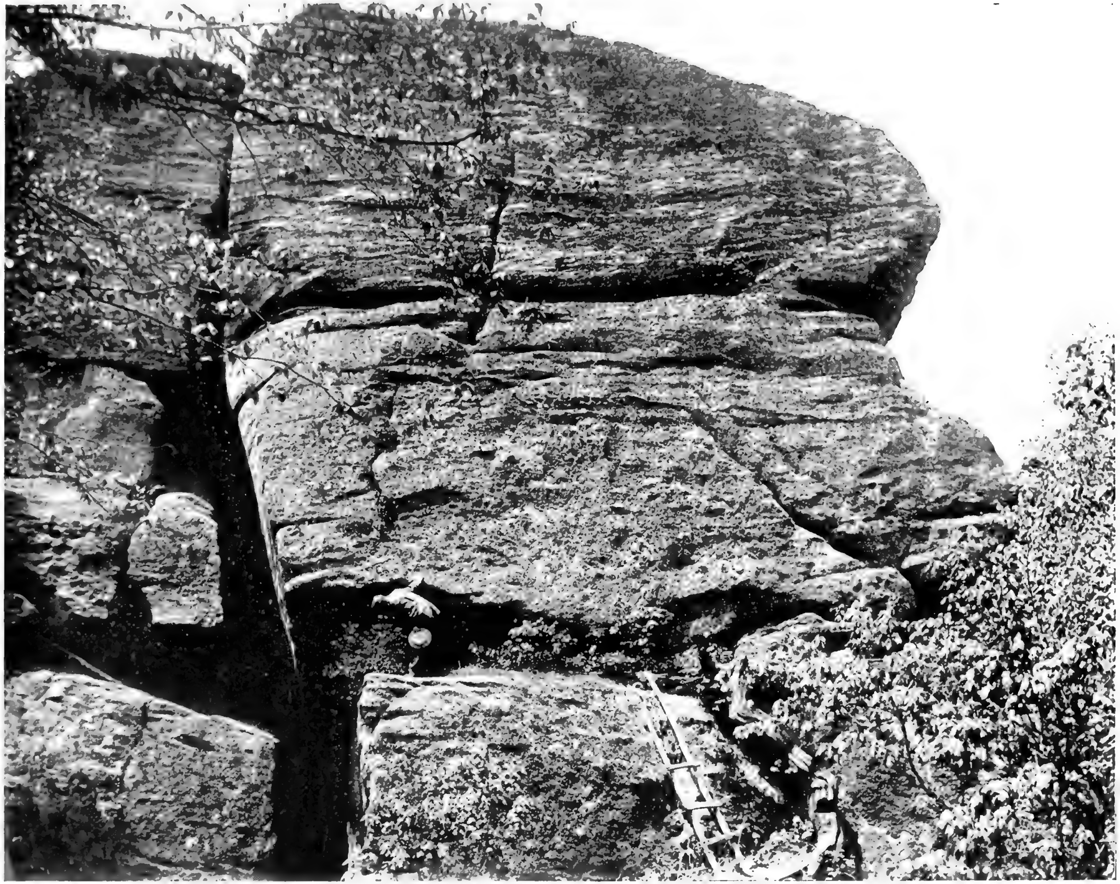
Olean Rock city. A weathered joint crevice

Plate 8



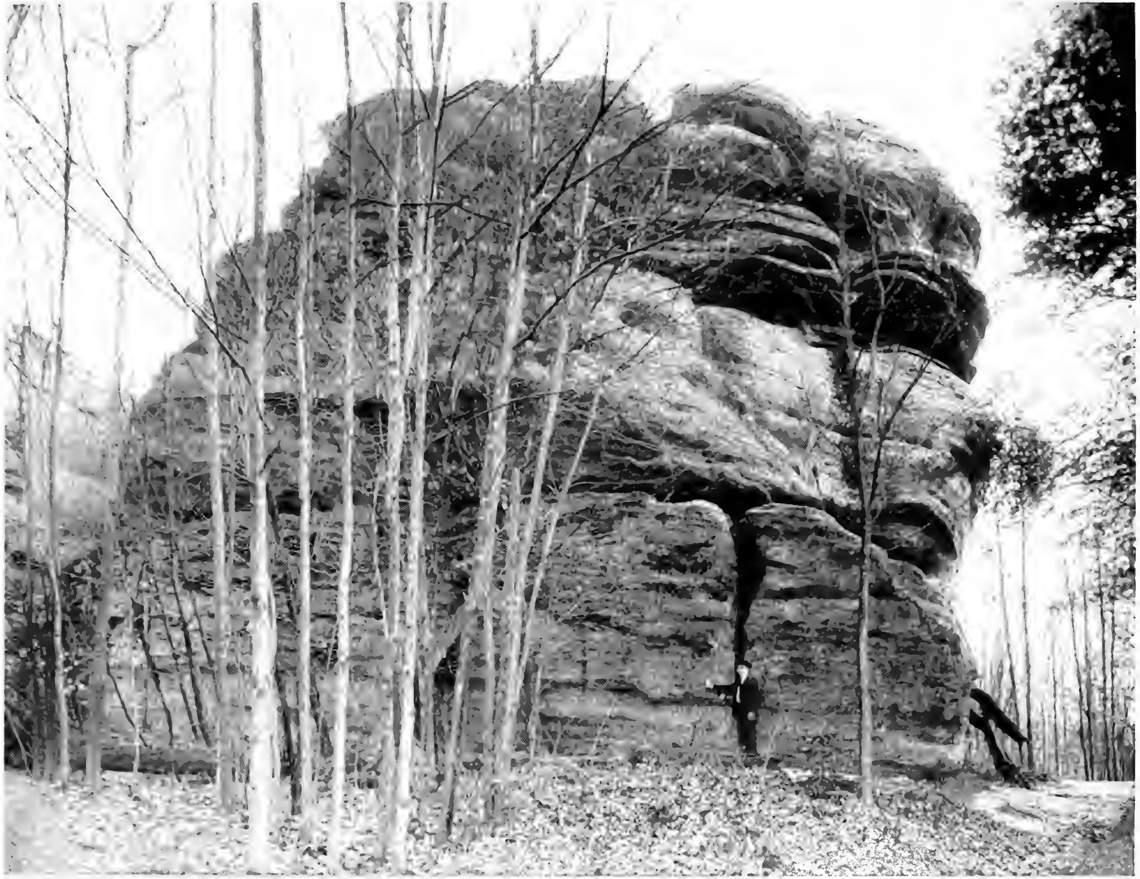
Olean Rock city. "The Swine's Snout"

Plate 9



Olean Rock city. Vertical and horizontal weathering

Plate 10



Olean Rock city. "Lone Rock," an isolated residual mass

Plate 11

Olean Rock city. "Lone Rock"

or that, the secondary silica has of itself been less resistant to atmospheric decomposition than the primary vein quartz of which the pebbles are apparently constituted. Yet it is not necessary to regard this secondary deposition as a large factor in cementation. Indeed cementation here has chiefly been effected by secondary crystal growth of the constituent pebbles. Some investigators have thought that the conglomerate pebbles displayed general evidence of etching under the action of organic acids. The eye is attracted at once by the glistening surface of these pebbles, reflecting the light from a multitude of facets, and these facets are all of crystal growth. Indeed pebbles are easily found wherein this crystal enlargement has gone forward to almost complete construction of the simple prism and pyramid with the original rounded pebble visible as a nucleus. This enlargement is general throughout the deposit and implies room between the pebbles for such growth; hence a very loosely cemented mass chiefly now held together by the locking of the secondary deposit. This general condition of weakness has been the cause of breaking down the rock beds wherever there are lines of slight resistance; thus principally along the almost rectangular series of vertical joints the dissolution here resulting in quadrate blocks standing like masses of floe ice floating on the sea.

Again easy passage through or between the strata has weakened and undermined the support of the blocks so that they have been tilted over at various angles. Thus the picturesque chasms, the sunken grassy walks, the rock bridges and the dangerous clefts are to be accounted for.

Examination of the original quartz pebbles under the crust of secondary growth shows sufficient evidence of the dynamic strains to which they were subjected in the formation of the rock masses from which they were derived, but of the geographical origin of these pebbles, what land it was that furnished them and by what lines of transportation they were brought hither are problems still remaining to be solved.

Supposed gold sands of the Adirondacks. The past year has witnessed a recrudescence of interest in the alleged gold-bearing sands of the Adirondacks. This office is frequently called upon for information on this subject, as well as for an expression of opinion regarding certain enterprises which have been inaugurated for the purpose of working such deposits on a commercial basis. The occasion seems opportune, therefore, to publish a general statement for the consideration of those who may have little

familiarity with the geology and mineral resources of that region. It is not within our province to offer personal advice to prospective investors, but it is proper to set forth the results of investigation and other matters of record that bear upon the matter.

There have been many attempts to promulgate a gold-mining industry in the region. The thoroughness with which the prospector for precious metals has covered the ground is to be seen in the abandoned pits and diggings that are scattered over every section. During the Klondike excitement, 10 or 12 years ago, the Adirondacks became the scene of a veritable rush for gold and practically every available sand heap was taken up for exploration. In the year 1898 alone there were filed nearly 4000 claims to gold and silver discoveries in the State, mainly within the Adirondacks.

The basis of all this activity is the alluvial and glacial sands which occur in almost every stream valley. These sands are not derived from remote regions to the north — though the opinion seems common that they have been transported by ice from Canada and even from as far away as Alaska — but are the result of erosive agents working upon the local rocks. They consist entirely of the minerals of the country formations which are chiefly granites, syenites, gabbros and gneissoid rocks of very ancient origin. Along with the lighter components, quartz and feldspar, there is a small proportion of the heavy minerals like garnet, pyroxene, hornblende and magnetite which have sometimes been separated by water action into distinct layers and which are found as black sands along the shores of the Adirondack lakes.

It is in these heavier concentrated portions of the sands that gold should be found if present anywhere in the region. Assays by reputable firms have occasionally shown a small quantity of gold, ranging from a mere trace to perhaps $1 a ton. The examination of innumerable samples under the microscope has failed to reveal any of the precious metals, though of course such evidence is not conclusive as to their absolute presence or absence. On the other hand the claim has often been put forth that the common quartz sands in certain places carry from $2 to $20 a ton, which, if true, would under ordinary circumstances bring them into the zone of practical exploitation.

The statement is commonly made by interested parties that the fire assay is unsuited to the determination of gold in these sands and special analytical methods must be employed. To this it can only be said that the fire assay has stood the test of long practice

in all the mining regions of the world. No reasonable explanation for its failure in the present instance has been forthcoming, though by the use of such vague terms as "volatile gold," "atomic condition" and "chemically combined gold," there seems to be an implication that the gold is driven off or left untouched by the fire. As a rule the gold found by fire assay is several per cent more than the amount extractable by the most refined commercial processes.

The exact methods for the recovery of the gold have usually been kept secret, out of the reach of scientific inquiry. They, rather than the mines themselves, seem to be the principal consideration in the organization of these ventures. From such information as has been given to the public, it would appear that they are generally based on some variation of well known methods or are a combination of processes in use elsewhere for gold recovery.

A good example of Adirondack practice, if it may be called such, is to be found in the so called Sutphen process which was in vogue about 10 years ago. Mills of ambitious design were erected at Hadley and Glens Falls for its exploitation. It involved pulverization of the sand, treatment with a secret solution, and amalgamation. The necessity for grinding the sand, already in a fine state, was alleged to be the distribution of the gold in the interior of the quartz grains. The success of the treatment, however, hinged on the character of the chemical solution, since the metal was stated to exist in combination with bromine and had to be set free before it would amalgamate. So much information was vouchsafed by the principals of the enterprise in an investigation by this Survey. A sample of sand taken from the bank from which the mill at Hadley was supplied showed by fire assay only a trace of gold, or less than 25 cents a ton, and no bromine. The enterprise received a great deal of attention during its brief career. The yield from the mill was said to have been as high as $7 a ton, and the working costs only $2.50 — a handsome margin of profit for gold mines of the present day.

It would appear as a matter of general experience that a necessary condition for the supposed widespread distribution of auriferous sands is the existence of quartz veins or other deposits of primary nature to which the sources of the gold could be traced. So far these have not been found, and in view of present knowledge of the Adirondacks, it seems very unlikely that they ever will be discovered. The quartz veins that occur in the region partake little

of the characters of those found in gold-bearing sections, being essentially destitute of iron sulfids and other minerals with which the precious metals are most generally associated. That they contain traces of gold is likely, but they do not afford any adequate basis for mining enterprise (except as possible sources of quartz) or for the accumulation of secondary deposits like placer sands and gravels.

There is little need for going further into details in this matter, though it may be said briefly that the Adirondacks form an independent geological and mineral province, only remotely related to the other mountain ranges of the eastern United States. The fact of the existence of gold deposits along the Appalachians from Nova Scotia to Alabama can scarcely be quoted, therefore, as an argument for the presence of analogous deposits in the Adirondack region.

While deficient in the precious metals, the region possesses the elements of large mineral wealth. Its production of iron ores, talc, garnet, graphite, pyrite and building and monumental stones of various character is a very important contribution to the mineral output of the country. There is abundant opportunity for future development of such resources and it is in that direction rather than in the seeking of the precious metals that energy and capital can be best employed.

The fact that the profits of mining are not to be gaged by the relative value of the mineral produced is a commonplace. If a balance could be struck, it would show probably that the homely iron ores better reward industry than all the gold and silver wherever found.

Industrial geology

Gypsum resources. With the growth of interest in gypsum and its products that has taken place in recent years, there has developed a need for a more thorough consideration of the New York deposits, commensurate with their commercial importance. Previous studies have afforded scarcely more than an outline of their field distribution and insufficient information of their character and utility, as in fact for a long time they were considered of small value except for local agricultural requirements. The discovery that the gypsum can be employed in the manufacture of calcined plasters has led, in the last decade, to the establishment of numerous enterprises, and there is every promise of a continued expansion in the industry for years to come.

Recent field investigations have extended from Madison county

west to Erie. The gypsum deposits are found in the upper part of the Salina formation which outcrops as far east as Albany county, but they attain workable dimensions only in the central and western areas where the Salina beds are thickest. Within this section which measures over 150 miles east and west they show a wide range of character, as one might expect; while there is also considerable variation in the size and sequence of the bodies.

Chemical analysis of various selected rock samples indicates that a relation more or less consistent exists between the composition and geographic distribution of the gypsum. In general it may be said that there is a progressive increase in the percentages of gypsum substance and a corresponding improvement in physical qualities as the deposits are traced to the west. This relation may be the expression of original conditions surrounding their accumulation which will later be considered. In the eastern counties the gypsum is admixed with clay, lime and magnesian carbonates and silica, the proportion of these impurities ranging up to 25 per cent or more of the whole mass. On the other hand the deposits in the western part of the belt show as little as 5 per cent of foreign ingredients and are much lighter in color.

The valuable bodies occur interbedded in the Upper Salina shales. They occupy usually large areas, as compared with their vertical dimensions, or in other words are stratiform. There are, of course, variations and irregularities to be found, but the stratiform type is the predominant and original one; the extreme departures from that type such as have been described and figured in the reports of James Hall and in Dana's *Manual* are in most instances to be regarded as modifications brought about by the solvent effects of ground waters. Besides the larger beds small seams of crystallized transparent gypsum, which appear to be secondary depositions, occur through the shales, so abundantly distributed in some places that the mixed shale and gypsum has been worked during times past to supply local needs for land plaster.

The forthcoming report will include a consideration of the origin of the gypsum, a subject that has economic bearings as well as geologic interest. Without entering into details of evidence here, it may be said that the gypsum is considered an accumulation from sea water evaporation contemporaneous in

general with the deposition of the accompanying shales and limestones. The rock salt which occurs lower down in the Salina is a product of similar conditions. Owing to the seemingly abnormal position of the main gypsum beds with respect to the salt and to the occurrence of irregular discontinuous masses near the surface, the view has sometimes been taken that the deposits represent former limestones which after their uplift were altered to gypsum by underground circulations carrying sulfuric acid. If this explanation were true the resources might prove to be limited, since their existence would be dependent upon purely local conditions. It is to be doubted, however, if such methods of origin can be applied to the valuable beds of rock gypsum.

Up to the present time the deposits have been attacked only at the more advantageous places on or near the outcrop. In the eastern section where they are thickest open-cut operations are the rule, while in Monroe county and farther west, they are commonly worked underground either from an adit driven from the face of a hill or by means of a vertical shaft. There has been little systematic exploration, but the need of it will come with the progress of the industry, particularly in the western counties which are the centers of plaster manufacture. The report will contain maps and other matter to indicate the more promising fields for future development.

Review of mines and quarries. The canvass of the mining and quarrying enterprises of the State, relative to the year 1908, showed that conditions were less prosperous than in the few years immediately preceding which were reviewed in former reports. The total value of the mineral production, itemized under 34 materials, was $29,519,785. The corresponding figures for the year 1907 were $37,141,006, so that the decrease amounted to about 20 per cent. The lessened activity was not, however, attributable to factors of local import, but to the wide-reaching depression that affected all lines of business. An improvement will doubtless be shown by the statistics for the current year, though the industry can hardly be expected to regain fully its former activity in so short a time. The iron mines perhaps suffered most from the financial stress owing to the fact that many of the properties were still in the developmental stage and without the resources of established enterprises.

The collection of the mineral statistics for the year was accom-

plished with the cooperation of the United States Geological Survey, under the agreement published in my last report, the two offices sharing the work and the use of the results.

Iron ore explorations. The Lake Sanford region, Essex co., was visited for the purpose of recording the recent developments that have taken place since the issue of the report on the Adirondack magnetites. Exploration with the diamond drill has demonstrated the presence of many millions of tons of ore, thus confirming the general opinion relative to the resources of the region. Experiments in the reduction of the ores are still under way and their favorable outcome will mean a very large increment to the mining industry of the Adirondacks.

Examinations have also been made of the Forest of Dean mine near Fort Montgomery and of the arsenical pyrites mined near Carmel, Putnam co.

SEISMOLOGICAL STATION

The seismographs in the basement of the State Museum have continued to render efficient service, with only occasional stoppages of short duration for the purpose of slight repairs or readjustments. Since their installation in March 1906 they have registered 54 different disturbances. The number registered during the year ending September 30, 1909, was 19 as compared with 9 in the preceding year. The seismic frequency has thus been rather notable, equalling in fact the record for the year 1907–8 which was distinguished by a series of very heavy earthquakes in Mexico, the West Indies and Central Asia, that involved many minor readjustments in their train.

The sources of the shocks in the past year have been fairly well distributed over the different seismic zones. The Cordilleran region, after the repeated rackings that followed the San Francisco earthquake and extended from Alaska to Chile, seems now to have settled down to a more normal condition. Slight tremors only have been reported from that region. The loci of pronounced activity have shifted to the east-west zone which extends from the Mediterranean coast to Central Asia where there have been several heavy earthquakes; of the number the Messina earthquake of December 28, 1908, involved the most appalling catastrophe that has ever been inflicted upon a civilized country. The shock itself does not appear to have been commensurate with the enormity of the destruction, the tracing obtained at Albany as well as at other stations showing

no remarkable features. Within the same zone belong the disturbances of India, Persia and western Europe of which records are included in the accompanying table.

As usual the local station has freely communicated its observations to those engaged in seismological investigation and to the press. Facsimile reproductions of the San Francisco records are included in the final report of the California Earthquake Commission recently published by the Carnegie Institute. It is hoped that a systematic exchange of records may be inaugurated between the several stations in the eastern United States and Canada; the comparison and coordination of data from a number of observational centers would be highly desirable.

In reference to the accompanying records it may be stated that the Albany station is equipped with two Bosch-Omori horizontal pendulums. One of these is set in the meridian and the other at right angles. The weight of each pendulum, including arm, is 11.283 kilograms and the distance of center of gravity from rotating axis is 84.6 centimeters. Their period is maintained at about 30 seconds; their multiplying ratio is 10. They have no artificial damping device. Albany is situated in latitude N. 42° 39′ 6″, longitude W. 73° 45′ 18″. The base of the instruments is 21 meters above sea level.

RECORD OF EARTHQUAKES AT ALBANY STATION, OCTOBER 1, 1908 TO OCTOBER 1, 1909

Standard time

DATE	Beginning preliminaries	Beginning principal part	Maximum	End	Max. amplitude
1908	h. m.	h. m.	h. m.	h. m.	mm.
October 13	12 18 a. m.	12 26 a. m.	12 32 a. m.	1 07 a. m.	2
November 6	2 50 a. m.	....	....	3 13 a. m.	....
November 30	4 50½ p. m.	4 57½ p. m.	4 58 p. m.	5 33 p. m.	2
December 27–28	11 40 p. m.	....	12 00 noon	12 19 a. m.	4
1909					
January 22	10 31½ p. m.	10 47 p. m.	10 47½ p. m.	10 56 p. m.	2
February 16	11 56 a. m.	....	....	12 13 a. m.	....
February 26	12 00 noon	12 05 p. m.	12 05 p. m.	12 30 p. m.	1½
April 10	2 06 p. m.	2 18 p. m.	2 19 p. m.	2 30 p. m.	1½
April 24	8 29 p. m.	....	....	2 38 p. m.	....
May 17	3 19 a. m.	3 21 a. m.	3 21 a. m.	3 48 a. m.	5
May 18	12 03 p. m.	....	....	12 23 p. m.	....
June 8	1 09 a. m.	....	....	1 40 a. m.	....
July 7	4 54 p. m.	5 01 p. m.	5 05 p. m.	5 45 p. m.	2
July 30	5 58 a. m.	6 12 a. m.	6 16 a. m.	7 09 a. m.	24
July 31	2 31 p. m.	2 41 p. m.	2 43 p. m.	3 20 p. m.	6
August 16	2 05 a. m.	2 15 a. m.	2 18 a. m.	2 44 a. m.	20
August 31	7 06 a. m.	....	7 16 a. m.	7 41 a. m.	....
September 8	12 00 noon	....	....	1 09 p. m.	....
September 22	9 54½ a. m.	10 02 a. m.	10 03 a. m.	11 30 a. m.	2

October 13. The vibrations continued for nearly an hour and their east-west component was the stronger. They appear to have been set up by a distant shock, perhaps originating in central Europe, which was in a state of unrest at about that time.

November 6. Very small vibrations of which only an east-west component was recorded. Severe earthquakes were felt in Italy, central Europe and southwestern Asia at corresponding times. They were probably preliminary to the Messina disturbance of December 28th.

November 30. Well marked though small vibrations of about equal magnitude on both instruments. Origin unknown.

December 27–28. A record of the disastrous earthquake at Messina, Italy. The vibrations at this station lasted about 40 minutes and reached a maximum amplitude of 2 millimeters at 12 midnight. Only very faint movements were shown by the east-west pendulum. Other stations in this country and in Europe reported the wave motion to have been of moderate dimensions. The earthquake was due probably to crustal dislocation along the depression occupied by the straits of Messina.

January 22. Record of devastating earthquake in the province of Luristan, Persia, in which 60 villages were wholly or partially destroyed. The shock was of world-wide compass and was reported by almost all stations. No direct news of its effects in Persia was received till February 17. The vibrations at this station were of about the same intensity as those set up by the Messina earthquake, though they traveled a much greater distance. No vibrations were indicated on the pendulum recording the north-south component.

February 16. The shock traveled apparently in an east-west direction. The movements lasted for 17 minutes with oscillations of small amplitude. They may be referred to the violent shock that was felt throughout Alaska on the same day and reported from Skagway Lynn canal at 7.30 a.m.

February 26. Record more clearly indicated on the east-west instrument. The epicenter is estimated at 2500 miles distant. The shock was also recorded by the Ottawa station.

April 10. Record obtained only on the north-south instrument. The shock was of moderate intensity, with a maximum amplitude of 1½ millimeters. Its origin is unknown but appears to have been about 6000 miles distant, possibly in the eastern Mediterranean region.

April 24. Slight oscillations of unknown origin recorded by both pendulums.

May 17. Vibrations of moderate intensity; recorded also at Washington and Toronto. The origin is uncertain but has been assigned to Chile where earthquakes were felt at this time.

May 18. A series of vibrations of moderate intensity traveling in an east-west direction. Their origin is unknown.

June 8. Record of a slight earthquake which occurred in Copiapo, Chile.

July 7. The disturbance can be traced to the shock reported from various parts of India. The vibrations began at 4.54 p.m., which, with due allowance for difference in longitude and time of transmission, would correspond to about 3 a.m. at Bombay or between 3 and 4 o'clock a.m. in central India. The movements were of small amplitude and continued for about an hour. As India is on the opposite side of the globe, the movements were probably transmitted across the polar regions as well as in an east-west direction. Stations in Russia, Germany, Spain and Canada also reported the same earthquake.

July 30. A record showing vibrations of unusual intensity with a maximum amplitude of 24 millimeters. Both pendulums were affected equally and owing to the similarity of this record to other Mexican ones and to the calculated epicentral distance, it is believed that the epicenter was in Mexico or South America. The shock was also recorded at Ottawa and its epicenter placed in Mexico.

July 31. Vibrations very similar to those of July 30, but of much less amplitude. This record probably represents the earthquake felt in Mexico City.

August 16. The record of a small earthquake reported near Mexico City. The record which is unusually distinct and regular, shows an amplitude of 20 millimeters and a duration of movement of about 40 minutes. Records were also obtained at the Ottawa, Baltimore and Washington stations.

August 31. Very small vibrations recorded on both pendulums. Possibly represents the vibrations from a slight earthquake reported in Rome, Italy.

September 8. A small movement indicated on the seismographs at this station, Ottawa and at Washington. The origin was calculated to have been 4000 miles distant.

September 22. A vibration of moderate intensity and con-

tinuing for about 2 hours. This origin can possibly be assigned to southern Europe since earthquakes were reported from France and Italy on this date.

MINERALOGY

In the section of mineralogy the work of investigation for the past year has included the completion of the memoir on the crystal forms of New York calcite, now in press, and several short papers on New York occurrences as well as two short crystallographic notes on the calcite from the New Jersey trap region, closely extralimital.

The rapid advances of crystallographic knowledge in recent years, resulting in the publication of a very considerable number of papers in all languages, has created the necessity for a systematic arrangement of the new forms added to all the important mineral species since the publication of Goldschmidt's *Index der Krystallformen der Mineralien* in 1891. So essential to the work of crystallographic investigation has this tabulated knowledge become that a card catalogue of the new crystal forms recorded since 1891 has been undertaken. This catalogue which has been completed through the letter I, indexes up to that point 1107 new forms. The catalogue records the letter, symbol, author, publication and date and has been compiled from all available sources.

The work of cleaning and preparing for exhibition the large suite of calcite from Sterlingbush, Lewis co., has been undertaken and is now well in progress. The exceptional quality of this material, when freed from the incrusting layer of stalactitic carbonate of lime, fully justifies the high estimate of its beauty and value formed from its appearance in the rough. Most of the large crystals show beautiful coloring and interesting multiple twinning. It is hoped that the many duplicate specimens of this enormous and valuable series will prove to be highly profitable exchange material.

Many valuable specimens have been acquired during the past year by purchase and exchange, including a fine specimen of the new species natrochalcite and representative specimens of the rare minerals cabrerite, kröhnkite and newberryite. A fine series of trap minerals from the new Erie Railroad cut at Bergen Hill, N. J., has been added to the already representative collection from that region. This latter series which includes beautifully crystallized specimens of apophyllite, analcite, natrolite, datolite, stilbite and calcite, has furnished material for investigation under the last

named species.[1] A collection rich in minerals from the Sterling iron mine at Antwerp, Jefferson co., has been acquired by purchase from R. S. Hodge of Antwerp. This contains many fine specimens of millerite from this locality, an occurrence now fast becoming rare by reason of the closing of the mine; as well as a highly representative series of crystallized hematite, dolomite, ankerite, quartz and calcite. A series of pseudomorphs of serpentine after garnet was collected from a locality about 2 miles north of Saratoga.

PALEONTOLOGY

Monograph of the Eurypterida. In my report of last year reference was made to this undertaking, which was inaugurated because of the amazing profusion of these extinct creatures in the rocks of this State. No other part of the world has afforded such variety and abundance of these ancient arachnids and our large collections have supplied much exact and unrecorded knowledge of their morphology and bionomy. Some time has been spent in the acquisition of additional supplies of material desired before bringing the monograph to its conclusion and about one thousand pounds of specimens were taken from the localities in Herkimer county.

The localities which have afforded the extensive suites of these fossils are, under present conditions, not accessible and some of them do not promise much for the future.

1 The celebrated development of the fauna in the Bertie waterlimes on the property of the Buffalo Cement Company, seems to be now approaching exhaustion. The eurypterids here have occurred in great numbers and splendid preservation, constituting some of the most striking fossil remains in the rocks of the State. Specimens from these quarries became scattered through the museums of the world, but fortunately before they were too freely dispersed the owners of the quarries determined to keep future discoveries of the kind together in the museum of the Buffalo Society of Natural Sciences, where today the Bennett Collection affords the most extensive series of these fossils from that locality. This occurrence in the waterlimes of Erie county seems to have represented a shore pool where the mature animals resorted for feeding or burrowing, but that it was not a breeding ground is suggested by the general absence of immature remains.

[1] Whitlock, H. P. Calcite from Jersey City, N. J. Fifth Report Director of Science Division, p. 219.

2 The black Pittsford shale of the same Salina formation which was exposed only by operations in widening the Erie canal, has no known surface outcrop. All the remarkable specimens recovered here were taken when the rock was fresh and there is little hope of adding to this material until the formation is again opened by civic improvements.

3 The historic localities of eurypterids in Herkimer county, in the region from Sauquoit to Wheelock's hill, have been so carefully searched that even the stone walls of the region have been quite fully overhauled. There are no known outcrops of the waterlimes in this region that now promise very much additional material or knowledge. Last year an old barn was found near Crane's Corners, whose foundation wall was largely composed of thin waterlime Eurypterus slabs taken from an outcrop no longer accessible. This foundation we removed without disturbing the building, replacing it with concrete as the removal progressed and it seems probable that the large material thus acquired is the last extensive series of these fossils to be hoped for from this region for some years to come.

4 The black shales in the Shawangunk grits at Otisville, Orange co., from which the very remarkable and extensive series of development stages were derived a few years ago, are now no longer exposed. These were shown mostly in a quarry where the sandstone was being torn out for construction of a branch of the Erie Railroad. That work is now finished and the sandstone wall stands sheer and steep with the thin Eurypterus shale beds tight in between its layers.

Aside from these four occurrences, specially noteworthy because of the abundance of their specimens, there are occasional examples to be found along the line of Salina outcrops in western New York, as at Union Springs, but these are rare and usually individual occurrences.

The monograph on these fossils is now brought to completion and early publication is hoped for.

Herein, in the chapter on morphology, a restoration of the muscular system is attempted and evidence brought forward in support of the view that the scales of the integument are muscle scars; the structure of the compound eye of Pterygotus is recognized as consisting of an outer smooth cornea with an inner system of papillary prolongations of the cornea serving as lenses, and thereby the homology of the eye of Pterygotus with that of

Limulus is demonstrated; it is shown that the chelicerae of Pterygotus consist of but three joints as those of the other eurypterids, the long proximal joint being undivided.

The probable mode of life of these strange creatures has been subjected to a thorough discussion and the conclusion reached that their life habits were not always uniform; on this basis they can be divided into four groups, as evinced by the form of their bodies and appendages; these groups being typically represented by Pterygotus, Eusarcus, Eurypterus and Stylonurus. In the first, forms of principally the swimming habit prevailed; the second were mud-grovelers and crawlers; the third are slightly specialized forms that were crawlers, burrowers and swimmers; the fourth were crawlers.

From the character of the rocks in which the Eurypterida occur and from the associate faunas, it is inferred that the eurypterids were originally marine animals, but at the time of their climacteric development in the Upper Siluric had become inhabitants of the lagoons and estuaries and were typically euryhaline, i. e. able to live in both salt and brackish water, and that this habit which they held throughout the Devonic, led them finally into the evident fresh-water habit of the expiring species in the coal lagoons of the Carbonic and Permic.

The collection of larval stages (some but 1 millimeter long) of the genera Eurypterus, Eusarcus, Stylonurus, Hughmilleria and Pterygotus has furnished data on the ontogeny of these genera which allow the following general inferences: (1) that the carapace is relatively larger in the larval stages, (2) that the compound and lateral eyes are relatively much larger than in the mature stage; (3) that they are nearer the margin; (4) the ocellar mound is large and more prominent; (5) the swimming feet are larger; (6) the abdomen lacks the distinct differentiation into pre- and postabdomen; (7) the number of segments is less; and (8) the telson spine appears to have been less developed.

Of these characters the relatively larger size of the carapace, compound eyes and swimming feet, and the smaller number of the abdominal segments are considered as cenogenetic or purely larval characters, while the approximation of the compound eyes to the margin, the prominence of the ocelli and their tumescences, the lack of differentiation of the abdomen and the smaller size of the telson, are held to be palingenetic and of phylogenetic

significance. In these palingenetic characters the nepionic stage resembles the Cambric eurypterid Strabops (Strabops stage).

The relationship to Limulus is indicated by a number of larval characters common to both the eurypterids and Limulus.

The prototype of the eurypterids has been reconstructed from the palingenetic characters of the nepionic specimens and the Cambric Strabops. By comparison of the later genera with this prototype the conclusion is reached that two separate families have been developed, the Eurypteridae and the Pterygotidae. In the latter family the genus Hughmilleria evinces the most primitive structure and Pterygotus and Slimonia have developed in different directions. The main stem of the stock in the family Eurypteridae is found by the genus Eurypterus which appears as the earliest in the Clinton and persists into the Permic. From it branch off Eusarcus and the subgenus Onychopterus which points the way to Dolichopterus, Drepanopterus and through the latter to Stylonurus.

The observations of the larval stages have been used in the investigation of the taxonomic relations of the Eurypterida. It has been found that the larval stages of the eurypterids and Limulus have all important characters in common, and that the differential characters are due to purely adaptive changes or are cenogenetic. While thus the close relationship of the two is also supported by ontogenetic facts, evidence is brought forward for the conclusion of a Precambric separation of the Xiphosurans and eurypterids. The larval stages of the eurypterids are further compared with those of the scorpions and evidence of relationship found through descent from a common ancestor. A comparison of the larvae of all three, the eurypterids, Limulus and the scorpion, has shown that both the latter have lost the primitive form of the abdomen by acceleration in which the eurypterids have best preserved the original gradual and uniform contraction, and that all three are derivable from a common ancestor to which the eurypterids are still nearest in their general aspect. It is further inferred that this common ancestor is more primitive than the crustaceans and may have to be sought among the annelids.

Monograph of the Devonic Crinoidea. Opportunity for the prosecution of this undertaking is limited to the few weeks each year that can be controlled by Mr Kirk who has been carrying on the study for several years under the conditions indicated. The

work as a whole is well advanced and as it covers a field of essentially new knowledge in this State, may constitute a substantial contribution to paleontologic science. During the past two seasons quite extensive discoveries of crinoids have been made by Mr Luther in the Chemung shale of the town of Italy, Yates co., all of which prove to be new and noteworthy additions to the crinoid fauna of the rocks. The progress made in these studies is indicated by the statement of the families represented and the species recognized.

INADUNATA

Family CYATHOCRINIDAE

Arachnocrinus bulbosus *Hall.* Onondaga limestone
A. *sp. nov.* Onondaga limestone
A. *sp. nov.* Onondaga limestone

Family DENDROCRINIDAE

Cosmocrinus ornatissimus (*Hall*). Portage fauna
Maragnicrinus portlandicus (*Whitfield*). Portage fauna

Family PISOCRINIDAE (?)

Hypsocrinus fieldi *Springer & Slocum.* Hamilton shale

Family CALCEOCRINIDAE

Halysiocrinus secundus (*Hall*). Onondaga limestone

ADUNATA

Family PLATYCRINIDAE

Cordylocrinus plumosus (*Hall*). Coeymans limestone
C. plumosus *var.* parvus (*Hall*). Coeymans limestone
C. plumosus *var.* ramulosus (*Hall*). Coeymans limestone
Platycrinus eriensis *Hall.* Hamilton shale

Family MARSIPOCRINIDAE

Marsipocrinus tentaculatus (*Hall*). Coeymans limestone

Family HEXACRINIDAE

Hystricrinus eboraceus (*Hall*). Hamilton shales
H. *sp. nov.* Chemung fauna
H. *sp. nov.* Portage fauna

CAMERATA

Family RHODOCRINIDAE

Acanthocrinus spinosus (*Hall*). Hamilton shale
Rhodocrinus nodulosus (*Hall*). Hamilton shale
Thylacocrinus gracilis (*Hall*). Hamilton shale

Family DIMEROCRINIDAE

Thysanocrinus arborescens *Talbot.* Coeymans limestone
T. *sp. nov.* Hamilton shale

Family MELOCRINIDAE

Mariacrinus nobilissimus *Hall.* Coeymans limestone
M. pachydactylus *Hall.* Coeymans limestone
M. paucidactylus *Hall.* Coeymans limestone
Melocrinus breviradiatus *Hall.* Hamilton (?)
M. clarkei *Williams.* Genesee-Portage faunas

Family DOLATOCRINIDAE

Dolatocrinus glyptus (*Hall*). Hamilton shale
D. lamellosus (*Hall*). Onondaga limestone
D. liratus (*Hall*). Hamilton shale
D. speciosus (*Hall*). Onondaga limestone
D. *sp. nov.* Hamilton shale
D. *sp. nov.* Hamilton shale
Gen. nov.
    troosti (*Hall*). Hamilton shale
Gen. nov.
    sp. nov. Onondaga
    sp. nov. New Scotland

Family BATOCRINIDAE

Coelocrinus cauliculus (*Hall*). Hamilton shale
C. praecursus (*Hall*). Hamilton shale
C. *sp. nov.* Hamilton shale
C. *sp. nov.* Hamilton shale
Gennaeocrinus carinatus *Wood.* Hamilton shale
G. eucharis (*Hall*). Hamilton shale
G. nyssa (*Hall*). Hamilton shale
G. *sp. nov.* Hamilton shale
Megistocrinus depressus *Hall.* Hamilton shale
M. ontario *Hall.* Hamilton shale
Gen. nov.
    sp. nov. Hamilton shale
Gen. nov.
    sp. nov. Hamilton shale

Postglacial mammalian remains

Mastodons. In my report for 1903, a summary was given of the recorded discoveries of the mastodon in this State since the first finding of such relics in 1705, and it was accompanied by a map indicating their geographical distribution. The list there given afforded evidence of about 60 distinct occurrences.

In my report for 1906 the record was supplemented by 4 items, and in 1907 by 2 more. In order to keep this record as complete

as practicable there are now added the following items which have either escaped notice or are more recent discoveries.

1884 Perry, Wyoming co. The Museum of the Wyoming Pioneer and Historical Association at the Silver Lake Assembly, contains two teeth found on the farm of William Olin, town of Perry, in the year indicated.

1908 Kill Buck, Cattaraugus co. A single tusk has been reported as found at this date near the banks of the Great Valley creek. Details are wanting.

1908 Batavia, Genesee co. Discovery of a part of a skeleton on Willow street in this village has been reported. The bones found consisted of a few ribs, vertebrae and leg bones and it is stated that a jaw bearing teeth was also uncovered.

1908 Manchester, Ontario co. A tooth on the property of Leonard S. Lyke.

Bison. Some teeth obtained in the postglacial clays of the Hudson valley a few miles below Albany, in deposits commonly regarded as laid down during that stage of the Mohawk drainage of the Great Lakes, termed Lake Albany, have been identified by Dr O. P. Hay as those of the bison. Although entirely exact data concerning the date and location of this discovery are wanting, these teeth have come into the museum within the writer's recollection and have been kept in association with a series of other mammal relics from this vicinity. The occurrence is of interest and the only instance we can now refer to of the presence of the buffalo in eastern New York during this epoch of postglacial waters.

Moose. The Barge canal prism northwest of Waterford, Saratoga co., passes along side the site of a buried Mohawk channel. In the course of construction of foundations for guide piers between the proposed locks a number of deep potholes have been encountered, similar in date and origin to, and only a mile and a half away from, those on the Mohawk at Cohoes, in one of which the Cohoes mastodon, now in the museum, was found in 1866. The largest pothole encountered at Waterford measured 16′ by 20′ in diameter and was excavated to a depth of 14′; no attempt was made to reach the bottom of the hole. The rock surface at the top of the potholes lay buried under 10′ of laminated clays (Lake Albany clay). At 14′ vertebrae and ribs were found which have been identified by Dr F. A. Lucas as those of the *moose.* With them in the clays, were shells of the genus Planorbis, moss (Sphagnum), wood and cones. The cones have been

examined by the State Botanist who identifies them as the white spruce (Picea canadensis) and states that the nearest point known to him where this tree now grows is Olmsteadville, Essex co. This is very interesting evidence of the change in life and climate which has passed since the moose wandered through forests of white spruce in the vicinity of Waterford.

III

REPORT OF THE STATE BOTANIST

The work of the State Botanist during the season of 1909 has been chiefly devoted to the collection and preparation of specimens of plants for the State herbarium, the preparation of descriptions and in some cases of colored illustrations of those considered new or edible species, the trial of the edible qualities of those which gave promise of edibility and the identification of specimens sent or brought to the office for that purpose.

Specimens of plants have been collected in 10 counties of the State and specimens have been received that were collected in 18 other counties and sent or brought to the office by correspondents or others. These specimens represent 56 species not previously represented in the herbarium and 77 species new to the State flora. Some of these were already present in the herbarium as varieties of species from which they are now separated as distinct. The total additions to the herbarium represent 255 species. The number of contributors is 66. The number of those for whom identifications of plants have been made is 152, the number of identifications made is 1717.

Notwithstanding the unfavorable character of the past season to the development of fleshy mushrooms, five species have been found, tried and approved as edible. This makes the number of New York species, now known to be edible, 200.

The climatic similarity between the growing season of 1908 and 1909 was very noticeable. Both were unusually dry and yet both were marked by an unusually abundant crop of the common edible mushroom, Agaricus campester L. In the latter season, however, the autumnal rains were much less severe and indicated a more favorable condition even for mushroom growth than the former. Besides the common edible mushroom an abundant and quite persistent crop appeared

of the garden mushroom, Agaricus campester hortensis Cke., which ordinarily is rarely seen growing wild. This indicates that gentle rains are better than severe ones, for this variety at least.

No evidence has been seen or received indicating any advance northward in the State of the chestnut tree disease, Valsonectria parasitica (Murr.), which proved so destructive to chestnut trees in the vicinity of New York city and Brooklyn two or three years ago. It is very probable that it has already reached its northern inland limit.

The favor with which the limited monographs of certain New York genera of fleshy fungi has been received has led to a continuance of this work. Accordingly descriptions of the New York species of the closely related genera Inocybe and Hebeloma have been prepared, together with synoptical keys to their subgenera and species.

A list of the genera of fungi previously treated in this way together with references to their respective places of publication, has been prepared by Mr S. H. Burnham, the assistant botanist. He has also prepared a list of the edible, poisonous and unwholesome fungi already published with their bibliographic references.

IV

REPORT OF THE STATE ENTOMOLOGIST

The State Entomologist reports that during the year thousands of young brown tail moth caterpillars in their winter nests were imported on shipments of nursery stock from France. The middle of June a small colony of nearly full-grown caterpillars of this species was discovered at Port Chester, N. Y. The thoroughgoing measures adopted in these instances appear to have resulted in the temporary extermination of these pests from this State.

Fruit tree pests. The most conspicuous injury to fruit the past season was undoubtedly caused by the hordes of plant lice which not only abounded upon apple trees but were exceedingly numerous on the cherry and more or less destructive to the plum. In consequence of the attack on the apple, the trees produced large numbers of small, gnarly fruit, which formed 35 to 45 per cent of the total fruit in some orchards. The exact records of the injury in the two experimental orchards will be

found in the full report of the State Entomologist. One apple grower estimated his loss at 50 per cent. This phenomenal outbreak coincided with unusually cool weather and was undoubtedly greatly favored by climatic conditions. The cigar case bearer was somewhat abundant in orchards in the western part of the State, though it was not so numerous as in 1908. The blister mite continued its injuries of last season and in some localities was much more prevalent, this being particularly true of the Hudson valley.

The San José scale continues to be one of the annoying pests of the horticulturist though progressive fruit growers have little difficulty in controlling it. The general experience with lime-sulfur washes has been highly satisfactory. A number of the commercial preparations of this material have given good results. Fruit growers are now beginning to use this wash in a more diluted form as a summer spray for plant lice and fungous diseases.

Codling moth. The codling moth is one of the very serious enemies of the fruit grower. A series of practical experiments were carried on through the season for the purpose of ascertaining the actual benefit resulting from the application of arsenical poisons, and also the relative efficacy of insecticides applied with a coarse or a fine spray. These experiments were conducted in the orchard of Mr W. H. Hart of Poughkeepsie and that of Mr Edward Van Alstyne at Kinderhook, N. Y. Great care was taken at the outset to secure an infested orchard with an ample number of trees likely to bear a nearly uniform amount of fruit. Each plot consisted of 42 trees, the fruit from the central six alone being counted. The others were used as barriers to prevent the treatment of one plot reacting upon the trees in another. These experiments involved considerable labor, since three sprayings were given in the case of the orchard at Poughkeepsie. It was furthermore necessary to sort and classify over 100,000 apples in this orchard alone. A reference to the data in the full report of the State Entomologist shows a most striking difference between the fruit from the sprayed and the unsprayed trees and indicates in no uncertain manner the supreme importance of thorough work.

Small fruits. The unusually severe injury by the grape blossom midge noted in 1908 was continued the past season though the insect may not have been quite so prevalent throughout the grape belt. The acre of early Moore grapes recorded as seri-

ously injured the previous year was badly damaged the past season. We were fortunate enough in early spring to rear the adult of this fragile midge which has hitherto escaped notice although the blighted blossom buds have been common for several years. Owing to the delay in issuing the report for 1908 it was possible to give, in that publication, a full account of the pest.

The grape root worm, though generally prevalent in the Chautauqua region, has not caused much alarm. This is due in part to a more thorough understanding of the insect and methods of controlling it, and also to better cultivation and fertilization. The latter are important factors in producing vines capable of withstanding injury.

Shade tree pests. The protection of our shade trees from the ravages of insect pests has continued, as it most assuredly should, to receive much attention. It is gratifying to record that the general public is displaying a very commendable interest in this phase of economic entomology. There have been numerous demands for information in regard to these pests and methods of controlling them. The supplying of such information has been an important part of the office work.

The elm leaf beetle has been somewhat prevalent in the Hudson and Mohawk valleys. It caused extensive injury for the first time in the city of Amsterdam and was quite destructive at Schenectady and also at Sandy Hill. There was general though not very severe injury in both Albany and Troy, while judging from reports this pest has been exceedingly destructive to elms on Long Island.

The spruce gall aphid, noticed in the preceding report, has continued abundant and rather injurious in widely separated portions of the State. It is a species which should be watched closely, since it is capable of causing severe damage, not only by destroying the terminal twigs and thus stunting the growth but also, as pointed out last year, by blasting the buds.

The sugar maple borer continues to be a serious enemy of maples. It was particularly abundant the past summer at Fulton, N. Y. A number of trees in that village were badly affected and a few were dying as a result of the recent work of this pernicious borer.

Forest insects. The ravages of forest insects are increasing in severity with the lapse of time. Our forest trees have suf-

fered greatly in recent years from outbreaks by leaf-feeding caterpillars. The snow-white linden moth has been one of the chief offenders. The past season was marked by extensive depredations by this pest. The flight of hosts of white moths about city and village lights, so generally noticed in 1908 was observed the past season.

The small, modest, grayish and olive-brown moths of the spruce bud worm attracted unusual notice in midsummer on account of their prevalence at street lights in a number of widely separated cities. These flights, judging from reports received, have been preceded by serious injuries to spruce trees in the Adirondacks.

The hickory bark borer, a most pernicious enemy of hickories, has been very injurious to the magnificent trees of Prospect Park, Brooklyn. Injuries by this pest have also been reported from the central portion of the State. This nefarious insect has in recent years destroyed thousands of valuable trees in this State. Its potentialities for evil amply justify the prompt destruction of infested trees.

Gipsy and brown tail moths. The appearance of the latter species in this State has already been mentioned and must be regarded as but the precursor of similar visitations. This insect has not, to our knowledge, become established west of the Connecticut valley, and it is to be hoped that the repressive measures, prosecuted jointly by the State of Massachusetts and the federal government will result in keeping this destructive form at a distance for some years to come.

The finding of numerous winter nests of the brown tail moth upon imported French stock last winter resulted in our conducting a series of experiments for the purpose of determining the efficiency of hydrocyanic acid gas as an agent in the destruction of the caterpillars. Though this most deadly gas has given excellent results with other species, it proved of no service in killing brown tail moth caterpillars within their nests, and could not be relied upon to destroy free caterpillars in a dormant condition at any reasonable strength and without an unduly prolonged exposure. The details of these experiments, showing the unreliability of this gas, are given in the full report of the Entomologist. On the other hand, dipping the caterpillars in a miscible oil placed upon the market under the commercial name of scalecide, was invariably followed by death.

There is still no authentic record of the gypsy moth having become established in New York State. The pest has not made its way nearer than the outlying small colonies known to exist at Springfield and Greenfield, Mass. The Entomologist has sent out a number of warning placards to places where these insects would be most likely to become established and as yet nothing suspicious has been discovered.

Miscellaneous. The large, steely blue insect known as Say's blister beetle was unusually abundant in the vicinity of Albany and occasioned some anxiety lest it prove a serious pest. There was a restricted outbreak of the army worm at Oakdale. Conditions were evidently rather favorable for more extended mischief by this insect, since the Entomologist found the caterpillars at Port Chester numerous though not very evident on account of the large amount of provender upon which they could subsist.

House fly. This insect, with its acknowledged potentiality for evil, is one of the most momentous of our injurious species. The present great interest in the house fly and methods for its control led to the devising of a vivarium or special house for the purpose of testing the behavior of this insect in relation to light and in particular to ascertain whether darkness or partial darkness could not be used as a barrier to keep this ubiquitous creature from breeding materials of various kinds. The house was a light-proof structure with partitions arranged in about the same way as those in the photographer's dark room, and flies were given a free opportunity to enter as far as they would with a constantly decreasing illumination and deposit eggs upon moist horse manure. The details of the experiments, given in the full report of the State Entomologist, show that this insect will not invade moderately dark places for the purpose of depositing eggs. It should be comparatively easy and very practical to store all such materials in dark or nearly dark places.

Gall midges. The work upon this group has been pushed as rapidly as possible consistent with the discharge of other duties. We have been able to make material additions to our knowledge of the biology of the group. This was particularly marked in the case of Sackenomyia, originally described from a female taken on the wing and now represented in addition by two reared species, of which both sexes, larvae and galls are known. The life histories of a number of species of Caryomyia, forms responsible for the peculiar and varied hickory leaf midge galls,

have been worked out. Likewise, a number of species of Cincticornia, a genus confined to oak, has been reared and some very gratifying data obtained. These by no means exhaust possibilities with this group, since material has come in so rapidly in recent months that it has been practically impossible to classify it adequately and at the same time collect or rear additional forms. Over 50 species have been reared during the year, most of them new and making a total in the collections of probably over 800 species, about 350 having been reared. This large number of specimens, in some instances species are represented by a hundred midges, is practically classified and only requires a relatively small amount of descriptive and collative work before being made available to the public.

Special acknowledgments in this connection are due Miss Cora H. Clarke of Boston, Mass., who has collected and forwarded to us large series of galls from which we were able to rear a number of previously unknown species. The care of this material devolved largely upon Mr D. B. Young, who has met with exceptional success in rearing the flies. Miss Fanny T. Hartman has assisted in caring for the biological material and has made excellent microscopical mounts of many of these extremely delicate midges.

Publications. Many brief, popular accounts dealing with injurious insects have been prepared by the Entomologist for the agricultural and local press and a few notices of more than general interest have been disseminated as press bulletins or through the agency of the Associated Press. A comprehensive popular bulletin on the *Control of Household Insects,* made advisable by the recent great advances in our knowledge of the relation of insects to the dissemination of disease in particular, was issued in May and is now, due to the great demand for such information, practically out of print. The report for last year, owing to delays incident to publication, was not issued till the last of the present year. A popular account summarizing one phase of our studies of gall midges and entitled: "Gall Midges of the Goldenrod," appeared in the *Ottawa Naturalist* for February. Biological data and brief descriptions of nearly 50 reared species of Cecidomyiidae were published in the issue of the *Journal of Economic Entomology* for August.

Collections. The additions to the collections have not been very extensive, since the amount of material already at hand de-

mands the expenditure of much time before it can be properly classified. Particularly gratifying additions have been made by rearing large series of Caryomyia, Cincticornia and Sackenomyia, the biology of these genera being previously unknown.

The general work on the arrangement and classification of the collection has been pushed as rapidly as possible. D. B. Young has identified practically all our species of Bombylidae, has done considerable work upon the Empididae and made substantial progress in classifying the Sapromyzidae, the Tabanidae and the Sciomyzidae. Mr Young is also responsible in large measure for the preparation of the list of insect types in the New York State collection given elsewhere. Much of Miss Hartman's time has been devoted to the care of breeding material, to mounting and labeling, to interpolating specimens, particularly Microlepidoptera in the general collections, and to bibliographic work.

Several greatly enlarged models representing injurious insects or portions of such forms have added very much to the educational value of the entomologic exhibit. A list of these models is given in the full report of the State Entomologist. This is only the beginning of what should be done along this line, since if one may judge from the work of other museums, the practical value of the exhibit collections has been greatly enhanced by accurate and tastefully executed models of important species. It is to be hoped that provision can be made shortly for the continuance of this work along broad and comprehensive lines.

General. As in past years, the work of this office has been greatly facilitated by identifications of certain species through the courtesy of Dr L. O. Howard, Chief of the Bureau of Entomology, United States Department of Agriculture and his associates. Several correspondents have been of material service in securing valuable specimens of one kind or another and as heretofore there has been a most helpful cooperation on the part of all interested in the work of this office.

V

REPORT ON THE ZOOLOGY SECTION

During the past year, in accordance with the policy stated in the last report, attention has been given entirely to the collections, and while the actual additions are not as great as might be desired, considerable work is under way that should be completed during the coming year.

The large group of black bear mentioned in my last report has been completed and the result makes a very effective exhibit. Through the courtesy of Pres. William J. Milne it has been temporarily placed in one of the new buildings of the State Normal College and will remain in its present quarters until the completion of the Education Building gives it a permanent home.

A group of moose has also been obtained consisting of a bull, a cow and a yearling. This is at present in storage as we have no place suitable for exhibiting it.

The taxidermist has prepared a habitat group of mink showing the animals by a pool of water in the foreground, the background representing an Adirondack scene which was painted by Mr D. C. Lithgow.

A group of sunfish and perch, of the same type, is also ready. This exhibits the fish swimming in the water among pond lily stems and weeds. The pond lilies themselves are shown on the surface of the water. This is the only fish group in which a successful attempt has been made to show both the surface of the water and a section through it. The exhibition of these groups has been delayed awaiting the procuring of cases, but they should be ready for public display by the beginning of the year.

The museum has also secured the necessary material for groups of porcupine, black rats, white-footed mice and several birds; while groups of wolf, puma, fisher and Canada lynx are in course of preparation.

The museum has been particularly fortunate in securing from Mr Austin Corbin, president of the Blue Mountain Forest Association, the promise of the material necessary for making up a group of buffalo, which has already been redeemed in part by the gift of two specimens from his herd. This opportunity is taken of publicly expressing an appreciation of Mr Corbin's kindness and generosity in this matter.

The ornithological collection which is in far better and more complete condition than the other zoological sections, has been allowed to remain except for such specimens as were kindly furnished by friends of the museum.

The taxidermist has also been working upon wax casts of some of the batrachians, two of which are now on exhibition, namely, one of the spring peeper and one of the common wood frog. This method of exhibiting these soft bodied animals seems as satisfactory as any yet devised and the Zoologist hopes to have a series of these casts completed during the coming year.

Considerable work has been done on the collections of Mollusca with the end in view of making them accessible. This work includes the making of a card catalogue, as the museum possesses much molluscan material, including the very valuable Gould collection of types, and it is very desirable that this be so arranged and indexed as to become available to those interested in the subject.

Monograph of the Mollusca. A very wide public interest exists in the terrestrial, fresh-water and marine *mollusks* and to meet demands for exact information as well as to bring our acquaintance with the New York molluscan fauna up to present standards, a monograph of this group was inaugurated a few years ago. Progress on this work was made, though slow, and at the present time it is in charge of Dr H. A. Pilsbry of the Academy of Natural Sciences, Philadelphia, a leading authority on the Mollusca.

Dr Pilsbry's work thus far has been directed almost entirely to certain groups of small or minute forms upon which nothing had been done at the time the monograph was placed in his hands, either in manuscript or illustration, viz, the *Pupillidae,* the *Zonitidae,* the smaller *Endodontidae,* the genus *Strobilops,* the *Valloniidae* and *Cochlicopidae.* The work on these groups is practically completed except for the subject of distribution. It is hoped that by collections and correspondence, substantial additions to the New York records of many species may be made, and some additional species may be found in the State. Several species not hitherto reported from New York have already turned up in the material examined.

Considerable work has been done in tabulating existing records, with the view of ascertaining what districts in the State have not been closely examined for recent mollusks.

In appropriate connection with this work on the *Mollusca* a preliminary investigation has been undertaken of the occurrences of pearls in our streams and lakes and a general inquiry into the possibilities of the development of this interest and expansion of the pearl shell industry. The presence of pearls in our waters is less a matter of record than, at least so far as recent occurrences are concerned, of report and news. Their discovery, however, is ancient. The fresh-water clams which are known as the Unios, Anodontas etc. occur very freely in all our lime-bearing waters and it is well known that these mollusks were used for food by the aborigines, as witnessed by the shell heaps which have been

found near Binghamton and in other inland localities. The Indians also recognized and valued the fresh-water pearls, for these have been taken sometimes in large numbers from Indian graves, usually perforated for stringing on a necklace and "more than three score and ten" pearls of unusual size, now unfortunately discolored and partially decomposed, were taken from one of the burial sites in the Genesee valley. The list of these occurrences among the excavated remains of the aborigines is rather surprising.

The earliest historic records of the discovery of pearls here are of altogether recent date. The finding of the Queen pearl at Notch Brook, N. J. in 1857 is usually regarded as the first noteworthy discovery of the kind in recent times. In 1868 pearls were found in the fresh-water clam shells of the Mohawk valley near the city of Rome and one of them is known to have brought the price of $100 in the market.

The lakes and streams of central, northern and northeastern New York, specially those draining into the St Lawrence river, have yielded the largest, finest and most numerous pearls. 68 grains is the weight of the largest known New York pearl. It was found in the Grasse river in 1897 and sold for $800. Most of the pearls from northern New York are of a peculiar translucent white, often highly lustrous. Others are of a light pink or rose color. As a rule the pearls of the streams are more abundant and of finer quality than are those of the lakes, the latter being usually milky in color, lacking in luster and hence of inferior quality. While it is not at all likely that these pearls are now to be had in sufficient quantity as to justify any extended operations that would involve much expense, yet it is most desirable to have definite data in regard to their occurrence and the conditions governing them. Pearl culture has been attempted with various degrees of success in many countries, though seldom on the fresh-water mollusks. The results attained do not give promise of culture pearls of high quality, but nevertheless they have had a commercial value, and may, even here, be made to form an important accessory to the cultivation of the shells themselves.

Another economic phase of this subject is the market value of certain varieties of these clam shells for the manufacture of pearl buttons. There are at present more than a score of button factories in the State which annually consume thousands of tons of shells in their operations. At present their supply of fresh-water shells is almost entirely obtained from the Mississippi

valley at considerable expense, and the expense is further augmented by the extreme percentage of waste of the raw material in the process of button making. Indeed it often runs as high as 90%, and averages more than 80%, upon all of which transportation charges have to be paid from the western source of supply. It is not unlikely that the natural supplies of the New York streams would help to alleviate this situation, as experiment has shown that several of the New York varieties are suitable for button manufacture. There is no obstacle to the artificial propagation of these varieties in the streams that are by nature specially adapted to their growth. Indeed it is altogether as practical a proposition as the artificial propagation of fish. Probably all of the fresh-water mussels in our rivers are or may be capable of pearl production, but it is an interesting fact that the three or four varieties most suitable for button manufacture are also those which have yielded most frequently the best grades of pearls, and it is also entirely reasonable to assume that the propagation of the pearls themselves is within the scope of artificial methods, though so far as experience in other countries in this artificial creation of pearl secretions has gone, the results are of inferior grade. It follows, however, as a natural conclusion that if the number of mussels with pearl-producing possibilities is increased by artificial propagation, the chances are also greatly augmented for increase in the production of the pearls themselves.

This line of investigation has been taken up by Prof. Philip F. Schneider and will be continued in the hope of bringing it to a conclusion that may justify recommendations of public usefulness.

Birds of New York. In several previous reports I have made reference to progress on a monograph of the *Birds of New York,* last year giving a summary statement of the contents of the first volume. This volume is now leaving the press. Volume 2 is complete in manuscript and its printing will be forwarded as rapidly as the character of the work justifies.

On account of the widespread interest in this publication and in view of the general demand for copies of it, this occasion is taken to announce that, in accordance with the requirements of the Department, the work will be held for sale at the following price:

Volume 1 Introductory chapters; Local lists, Water birds and Game birds (Pygopodes, Paludicolae, Limicolae, Gallinae and Columbae), 42 plates in color......$3

Volume 2 Land birds (Accipitres, Striges, Coccyges, Pici, Macrochires and Passeres), 60 plates in color........$4

Purchasers of volume 1 will be at liberty to buy volume 2, when issued, at the price of $3.

VI

REPORT ON THE ARCHEOLOGY SECTION

Collecting in all of the various branches of this section of the museum has been necessarily subordinated to the work of procuring models and superintending the work of casting the figures and making the preliminary field sketches for backgrounds for the ethnological groups. The pressure of this undertaking made it impossible for the Archeologist to engage in active field work in archeology, although he made preliminary surveys of certain sites in central and southeastern New York.

In September the assistant in archeology was sent to Port Jervis to excavate the site of a Minsi village and burial ground which the Archeologist had previously examined at the suggestion of the Director. Little or nothing is known regarding the archeology of the Minsis nor was it possible to determine from an examination of the Port Jervis site much concerning their culture except in the line of their mortuary customs.

The Van Etten site, the site of the Minsi village and burial place is found on the Levi Van Etten farm on the east bank of the Minisink river, 2 miles from Port Jervis. It has been known for many years to the people of the region. Tradition as well as material evidence kept it constantly in the minds of interested persons. The annual spring freshets of the Neversink cut away the alluvial hill upon which the burial ground was situated and bones with accompanying relics would roll down the eroded bank and either be caught upon the sand bars or fall in the waters to be swept away and lost forever. A considerable number of collectors have visited the site and picked up the relics brought to light by rains and flood and several have excavated certain portions of it but with little success.

Excavations conducted during the months of September and October 1909 by the assistant in archeology resulted in the discovery of 30 graves and several hearths and refuse pits. The

latter contained little of interest, only a few potsherds and rude flints being found in them.

An examination of the burials proved that the Minsis had for some time been influenced by the white men about them. Some of the skeletons seem to have been buried in rough wooden boxes. The position of all skeletons found in what appeared to be the remains of boxes was the extended position instead of the flexed position generally found in old burials in this State.

Most of the objects found in the graves were of European origin. These objects include beads of several sizes and shapes, brass and iron finger rings, brass bracelets, brass bells of two forms, one bronze soup spoon, one clay pipe stamped R. Tippet, and brass buttons. The aboriginal artifacts found in the graves were all shell ornaments, probably pendants or gorgets.

Several of the skeletons present interesting features for study. There are several fractures and cases of ankylosis worthy of careful examination. Osteological studies of these skeletons are reserved for a future time.

The skulls are unlike any others which are found at present in our collections. They are flattened at the occiput evidently by artificial means, probably in early infancy by the agency of the baby-board. This occipital flattening gives the skull, as viewed from the front, a peculiar bulging appearance at the back.

An interesting series of stone articles from the lower Hudson valley has been received from the American Museum of Natural History in exchange for a collection embracing a number of duplicate specimens from western New York. The Hudson valley collection contains some good specimens of chipped and polished stone articles.

Through the activity of Mr D. D. Luther, the field geologist, an unusually good lot of articles has come to us from two ancient graves on the east slope of Bare hill, Canandaigua lake, near the village of Middlesex. The collection includes a knife of rhyolite, 10 inches in length. The chipping is good and the knife thin considering the poor quality of the material. With this knife was found a rude pipe of pottery. It has no decorations. In the same grave was a long string of shell and elk tooth beads, a copper chisel and two finely made stone tubes. A second grave contained a broken tube and a broken bar amulet. All of these objects are relics of a Pre-Iroquoian people and are similar to specimens found in mounds.

Plate 12

The Minsi burial ground is situated on the terrace above the flood plain of the Neversink river. The burials were found along the edge of the terrace and the village site was farther back.

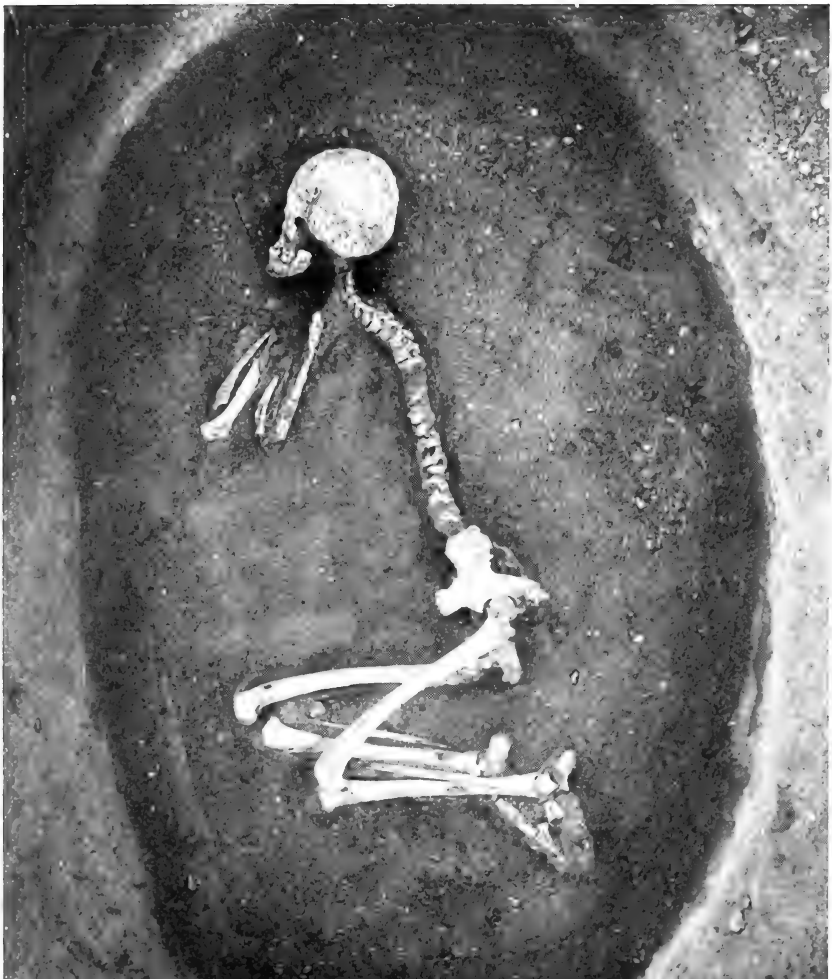
Plate 13

General view of the Minsi burial ground near Port Jervis. The expedition tents are shown in the middle distance.

Plate 14

Landslip caused by the underwashings of the substratum of sand at the water level. The landslides here frequently exposed skeletons and relics. The amount of land lost in five years can be measured by the fence posts in the middle distance.

Plate 15



Typical aboriginal burial of the Minsis. The camera was pointed directly down and over the grave. No specimens were found in this burial.

Plate 16

Extended position which characterized all burials where European objects were discovered with the skeleton. The beads shown on the neck are large opalescent glass trade beads.

Plate 17

Grave 28, Port Jervis Minsi site. Child burial, extended position. The objects shown in the grave with the skeleton are, a bronze spoon, a brass bell and a shell ornament.

Ethnology

In collecting ethnological specimens the policy of the Department is to acquire all that illustrates the Iroquois culture. Many of the specimens are old and have been preserved for years as heirlooms or keepsakes. Some of the specimens however are absolutely new, but their value is not lessened thereby. Such objects serve to illustrate the persistency of Iroquois material culture and are similar in all respects, save age, to specimens which have been kept through the years. Our aim is not to collect objects merely because they are relics, but to collect specimens which illustrate a material culture.

Some of the old arts of the Iroquois exist merely in the memory of a few aged persons and we have been seeking to revive these arts where we have few or no specimens of them.

Silver working and certain forms of basketry, weaving, porcupine quill and moose hair decoration, skin working, carving and beading have become almost lost arts and it is hoped that a revival of these arts by a few individuals will furnish our collections with certain specimens now impossible to obtain. If we were merely collecting antiquities this policy would not be feasible.

Notable additions to the collection. Several masks of the False Face Company (Ja'di'go^{n}'sa sho''o') have been added to the collection. Some of these are of unusual interest. One large mask representing the "ash blower" was purchased by the Director. This mask is one of the old and unusual varieties. Other masks are a "doctor" face, a "wolf mouth" and one having the eye-plates cut in semilunar form and the lips in the form of the figure 8 laid horizontally. The three masks last mentioned were obtained on the Cattaraugus Reservation during the midwinter ceremonies of the Senecas in January 1909.

There are yet many facts to be collected before a complete description of the Iroquois False Face Company can be written. This statement indeed holds good for the various folk societies. The Archeologist is using every opportunity to get at the facts and already has a large amount of data on hand.

During the Strawberry Thanksgiving in late June, the Archeologist made a special effort to get some additional information and succeeded in getting photographs of the officers of the False Face Company carving a "medicine" or "doctor face." Such faces are carved upon a living basswood tree and when com-

pleted the tree is chopped down. Its life is believed to enter the face which is chopped from the trunk and finished by the carver. During the process of carving an officer of the company throws tobacco, oyĕñ′kwa‘oⁿ′we‘, (*Nicotina rustica*) upon a small fire and chants the rite that makes the face a living potency. A photograph of the carving ceremony is shown in plate 18. The Archeologist obtained the false face on the tree-trunk carving and added it to the State Museum collection. So far it forms a unique specimen in collections of Iroquois artifacts.

One other carving, that of a wolf head used for placing over a door, was purchased. The head represents the token of the mother and children living within the house.

The Senecas have not used bark barrels for storage for more than 40 years. Barrels of elm bark once formed the chief means for storing corn and other provisions as well as goods of other kinds. Early in the year one of these elm bark storage barrels was found on the Cattaraugus Reservation and purchased by the Archeologist. It had recently been made by a Seneca whose mother had instructed him in the all but forgotten art. It is about 18 inches in diameter and 30 inches high and has a cover. The bark is sewed with the inner bark of the elm. In the entire object there is not a nail or a peg. The Algonquin Indians of Canada, particularly the Abenakis make barrels similar to this of birch bark but they are not as strong as the elm bark barrels of the Iroquois. A birch bark storage basket was purchased for comparison.

A good set of baskets used in planting, harvesting and food preparation was purchased from Mrs Edward Cornplanter of Newtown on the Cattaraugus Reservation. A paddle which was included in the collection had been promised for several years. This paddle had a number of grotesque figures carved upon the handle but some of the most significant from the standpoint of symbolism had been cut away.

An interesting war club made from the knot of a sapling root was secured from the Senecas. It has carved upon it representations of all the clan animals and two Indians engaged in combat.

Other unusual pieces are an Eagle Society speaker's pole, examples of modern silver work, wooden spoons, and several beaded articles, two of them old and very fine. Several charms and amulets were added to the already interesting series.

Plate 18

False faces are carved upon the living trunks of basswood trees by a wood carver chosen by the False Face Company. While he carves an officer of the company chants the carving song, casting native tobacco on the ceremonial fire as he sings. When the mask is rudely formed the tree is cut and the mask taken from the log to be finished elsewhere.

Folklore. Work in recording the folklore and ceremonials has been retarded this season by activity in other lines. Some notes, however, were taken and a very important manuscript secured through the courtesy of Rev. A. J. Farney of Ohsweken, Ontario. This manuscript is the version of the code of Daganowida, the founder of the Five Nations' League as adopted and written by the Six Nations' Council. The story describes the meeting of Daganowida and Hiawatha and gives a history of their subsequent activities. It concludes with a version of the Condolence ceremony extracted verbatim from Horatio Hale's *Iroquois Book of Rites,* a seeming tribute to the accuracy of Hale's work.

There is much work in the line of collecting lore of this character. It is becoming more and more difficult to get. The old people who have memorized the various rituals and legends are rapidly passing away and but few of the younger people have taken the pains to burden themselves with a knowledge of the old ways of their fathers. Some knowledge of this vast unwritten literature will undoubtedly pass down to the descendants of the New York Iroquois but much will be lost unless provisions are made for its preservation within the immediate future.

Public interest. Interest in the present and past Indian life of our State seems to be fast increasing. Students are turning with renewed activity to the subject of the ethnology of the New York Indians. Artists and sculptors are seeking accurate information in regard to the costumes and the customs of the Iroquois. Many hundred inquiries along these and similar lines have been directed to this section of the State Museum.

With a limited exhibition space, limited quarters, insufficient equipment, and the great bulk of our material in storage, we have been at great disadvantage. Students from many quarters representing well known institutions have made personal visits to our office and collections only to be disappointed in a large measure because of our limitations.

During the fiscal year just passed special attention has been directed to the Indians of our State through various historical celebrations, and yet with a great store of material, consisting of both facts and relics of Iroquois and Algonquin culture we had neither facilities nor time for bringing these things to public notice, so great was the demand of other things.

The Governor Myron H. Clark Museum of Iroquois Ethnology

To illustrate the culture history of the Iroquois we have designed a series of six ethnological groups.

To formulate plans and to select proper models, sites for painting and to carry out the numerous details incident to so large an undertaking has consumed the greater part of the past 12 months and has required constant activity.

The object is to portray in a material way the characteristic habits of Iroquois life. These life activities it will be realized in general were similar to those of other peoples living in the eastern forest areas and in the same cultural stage.

Ethnological groups have been installed in most of the larger educational museums in the United States and elsewhere and have universally proven most instructive exhibits. They add an element of realism impossible to secure by any other method. A group of casts properly arranged shows at a glance what would take many pages to describe and a great deal of shelf room to illustrate. The virtue of such groups is that the costumes, ornaments, implements and utensils are all properly correlated and their uses shown.

The most primitive activity of any people is the food quest. The greater part of savage man's food was secured by hunting. The hunting stage is one of the most romantic in the development of mankind. Its influence is so strong because of its character, and its period so extended in the history of all races that it has left an indelible impress upon the minds of all races, even those whose cultural stage is far above it. To this day the gratification of the hunting instinct gives enlightened men a great amount of pleasure.

A second activity of races is warfare. The conflict of man with man in warfare has gone on for thousands of years and until now there has been no thought of its abandonment. Warfare, cruel as it is and destructive as it is, has seemed a necessary part of human development. Art and inventions, heroism and intellect seem to have been stimulated by it. This is probably because each party in the conflict saw his own life and the existence of his tribe or nation in immediate peril and sought every means to avert it.

The logical outcome of any emergency is a council. Men congregate to discuss the means of warding off danger, defeating

enemies, or accomplishing desires which affect the entire body of people. The council would thus beget leadership and government.

Personal welfare, primarily, and group welfare, secondarily, being the consuming desire of men, every means real or fanciful, is sought to secure its attainment. A belief in supernatural agencies and the development of men who assume and are assumed to know something of these supernatural potencies, gives rise to certain rites and ceremonies thought to be conducive of welfare — luck or health as the case may be. Ceremony and religion thus enter into the life of ethnic groups with all their concomitants.

Social life so far advanced presupposes the existence of productive arts, that is to say industries by which implements, utensils, weapons, clothing, ornaments and other useful objects are manufactured. The character of these artifacts and of the methods of their production differ as the cultural stage, the cultural degree and the individual group development differ.

Up to this point the social group has nothing to localize it. The group may be nomadic for neither hunting, warfare, counciling, ceremony nor industry postulate sedentary life. Such life commences with some activity thought vital to group welfare and inseparable because of its character from a locality. Agriculture is such an activity and in agriculture we have the basis of group stability and group sedentarism. It confines a group of families to a certain general locality for at least a season. It creates community interest and crystalizes the group. With this development the people would cling to a locality for an appreciable period unless driven out by hostile groups or other causes.

In the lower stages of culture where agriculture has developed we find that villages take growth. Instead of a place of wanderers' tents or hunters' tepees we find houses of more or less stability. Trails or roads are built from village to village. Travel and traffic commence; civilization is now a mere matter of growth.

Upon the foregoing hypotheses the Archeologist has planned the character of the figure groups by which the ethnology of the Iroquois will be illustrated. Casts of the Iroquois Indians in various positions are being made and arranged in groups. These groups will illustrate the various life activities incident to the Iroquois culture. Our groups will differ from other ethnological groups in other museums in that a cycloramic painting will form the back-

ground. Months of study and visits to large museums have been made to establish the feasibility of this plan. The cases in which the groups are to be installed have a front of a little more than 20 feet and a hight of about 17. The depth of the case and the foreground in which the group is to be installed is about 12 feet. The glass front will be about 9½ feet in hight and 15 feet long. The case is so planned that when the visitor views the group no part of the interior of the case is visible. The point where the painting meets the top can not be seen, neither can the points where the sides meet the front of the case be observed. The object is to create the illusion that one is looking out through a large window at nature itself. The painting is made in such a way that the foreground with its artificial foliage and natural work meets almost imperceptibly with the painting — one seems a continuation of the other.

To illustrate the activities of hunting six Seneca Indians were selected as models and brought to New York city where they were posed in characteristic attitude and cast in plaster. Such figures show the tree chopper with his stone ax busy felling a tree by the charring and chopping process, the old hunter bringing in a deer, a boy with his traps and birds he has killed, a hunter with bow pulled back in the act of shooting a flying partridge, and two women one of whom is skiving a deer pelt and the other cutting venison into strips for jerking. These figures it must be borne in mind are exact casts from life, limb for limb, feature for feature, and even pore for pore, so exactly does the plaster reproduce the living model. As a background for this group of Seneca hunters a scene on Canandaigua lake was chosen. The Archeologist in company with an artist made a trip up the lake above mentioned and chose a site where a good view of Bare hill, the ancestral hill of the Senecas, might be had. Early Seneca history and tradition is so inseparably interwoven with associations with Bare hill and Canandaigua lake that it seems most appropriate to employ the scene as a background for the group of "primitive" Senecas.

As hunting is the most primitive activity of savage life, the hunting group will be the first of the series.

The second group for which casts have been made is that which illustrates some of the characteristic war customs of the Mohawks. The group is called *The Return of the Warriors.* It embraces six cast and modeled figures with others in the painted background. The group shows the advance party of warriors bringing in two

Algonquin captives. One of them labors under a heavy load of booty and expedition impedimenta and is being urged on by a gigantic Mohawk. An old sachem is kneeling on one side and examining a pack of skins, trinkets and seeds which has been brought in by the party but his interest is diverted to one of the captives who has thrown down his burden in defiance. A warrior with uplifted club is about to dispatch the haughty captive when a matron from the village asserting her right to adopt touches him and holds out a protecting hand. The angered warrior relaxes and has rested his club on his shoulder. In the presence of a woman his emotion is concealed.. His brow only shows a questioning wrinkle. Another warrior who has seen the affair turns on the brow of the hill and haloos down the valley to the chiefs who are leading the rest of the warriors back to the stockade.

The scene is laid at Tionnontogen the capital of the Mohawk Nation in 1667. Tionnontogen was the town and stockade destroyed by De Tracey. The site of this old stronghold is found on the Mitchell farm near Sprakers Basin, Montgomery co. The old village and stockade was situated on a little plateau that juts out into the flood plain of the river. On one side is a deep ravine that forms the east bank of Flat creek. Copious springs of pure water make the place an ideal one for an Indian town and the steep hills on three sides render it a good site for a fortification. The site of Tionnontogen commands one of the finest views of the Mohawk valley to be had. Just to the east, the high limestone "Noses" bar the vista, but to the north and west the river, the hills and the valley may be seen stretching far into a blue mist that covers the distant horizon.

There are many romantic events associated with Tionnontogen and the deep ravines and rugged hills and great stone "Noses" which give the spot its name only intensify the romance.

In making the sketches for this scene the artist took his position on a jutting ridge just over the ancient site. The scene is one of late autumn and in the large painting the artist will attempt to show it as it might have been when it was the center of Mohawk life.

To get casts of the Mohawks the Archeologist went with the sculptor to the Six Nations Reservation in Ontario where a month was expended in selecting proper models and in making molds.

Casts for a third group, the sixth in the series, were made during September. This group will portray the agriculture and harvesting activities of the Seneca-Iroquois. An old man strolls in from the right, holding his clay pipe in one hand and a bunch of

Indian tobacco (*Nicotina rustica*) in the other. Before him is a group of women engaged in gathering and preparing the crops. One is braiding corn, one is shelling beans and putting them in a bark storage basket, one is baking bread and watching a pot, another is pounding meal in a wooden mortar, and still another is carrying in a heavy load of corn. The scene is laid on the flats of the Genesee just below Squakie hill near Mount Morris, Livingston co. The painted sketch which was made on the spot shows a cornfield in the foreground, the river to the left with the cliffs just beyond. To the right is the steep slope of Squakie hill covered by oaks, hemlocks and maples, all resplendent in their brilliant autumn foliage. The spot is one associated with the later history of the Senecas and by some is said to have been regarded as their Olympus.

The Senecas were always extensive agriculturists and today preserve certain primitive features of agriculture better than the other Iroquois. The flat lands of the Genesee were cleared in wide tracts and given up to their great cornfields. These reasons with others lead to the choice of the Senecas and their beautiful valley, the Genesee, as the actors and the scene for the harvest group.

The Onondaga Council group, the Oneida Arts and Industry group and the Cayuga Ceremony group are still undeveloped beyond the plan stage.

The work of making and superintending the making of these remaining groups will consume another year. There are many unavoidable obstacles which impede progress of this undertaking and yet to those quite familiar with similar work our progress has seemed rapid.

It is difficult to get proper models, especially females whose natural modesty leads them to shrink from the casting process. The eight female figures which we have are without doubt the only life casts of Iroquois women ever made. Our casts of male figures likewise are, for the most part, phenomenally expressive.

In carrying out our plan the idea is to have every possible feature of it genuine. The casts are to be genuine life casts of Iroquois Indians, their costumes genuine Iroquois costumes, Iroquois made and decorated, and the paintings are to be accurate representations of scenery intimately connected with Iroquois history.

When installed each group as viewed from the front of the case will present the illusion of an actual view of nature. The foreground will be made to look as natural as possible by expert

leaf makers. Each group will form a unit around which will be clustered cases of implements, ornaments or utensils, the use of which is shown in the group.

The whole scheme when completed will furnish a comprehensive picture of Iroquois life in the precolonial period so far as that life can be interpreted through history, tradition and the present day survivals of the Iroquois culture.

For some years past the remains of the ancient Indian settlements in the Naples valley near the south end of Canandaigua lake, have been closely studied by Mr D. D. Luther, who has, in spite of the fact that the fields where these settlements stood have been ploughed over for more than a century, been able to acquire very positive evidence of their extent and of their early age. Mr Luther has given an account of this village on following pages of this report.

VII

PUBLICATIONS

A list of the scientific publications issued during the year 1908–9 with those now in press and treatises ready for printing is attached hereto. The publications issued are 13 in number on a variety of topics covering the whole range of our scientific activities. They embrace 1780 pages of text, 171 plates and 22 maps.

The labor of preparing this matter, verifying, editing and correcting is onerous and exacting. Taken altogether it excellently indicates the activity and diligence of the staff of this division.

Annual report

1 Fifth Report of the Director, State Geologist and Paleontologist for the fiscal year ending September 30, 1908. 234p. 39pl. map.

Contents:

Memoirs

2 No. 9 pt 2 Early Devonic of New York and Eastern North America. By John M. Clarke. 250p. 36pl. 4 maps.

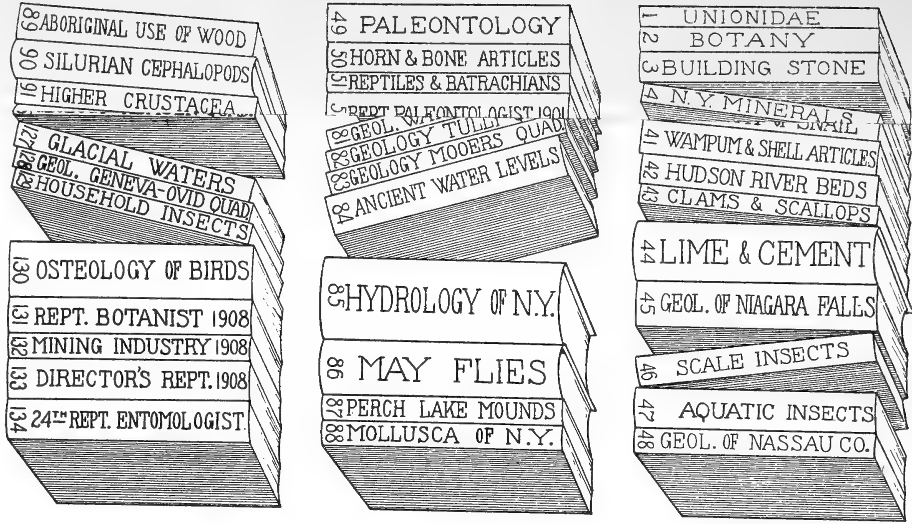
Contents:

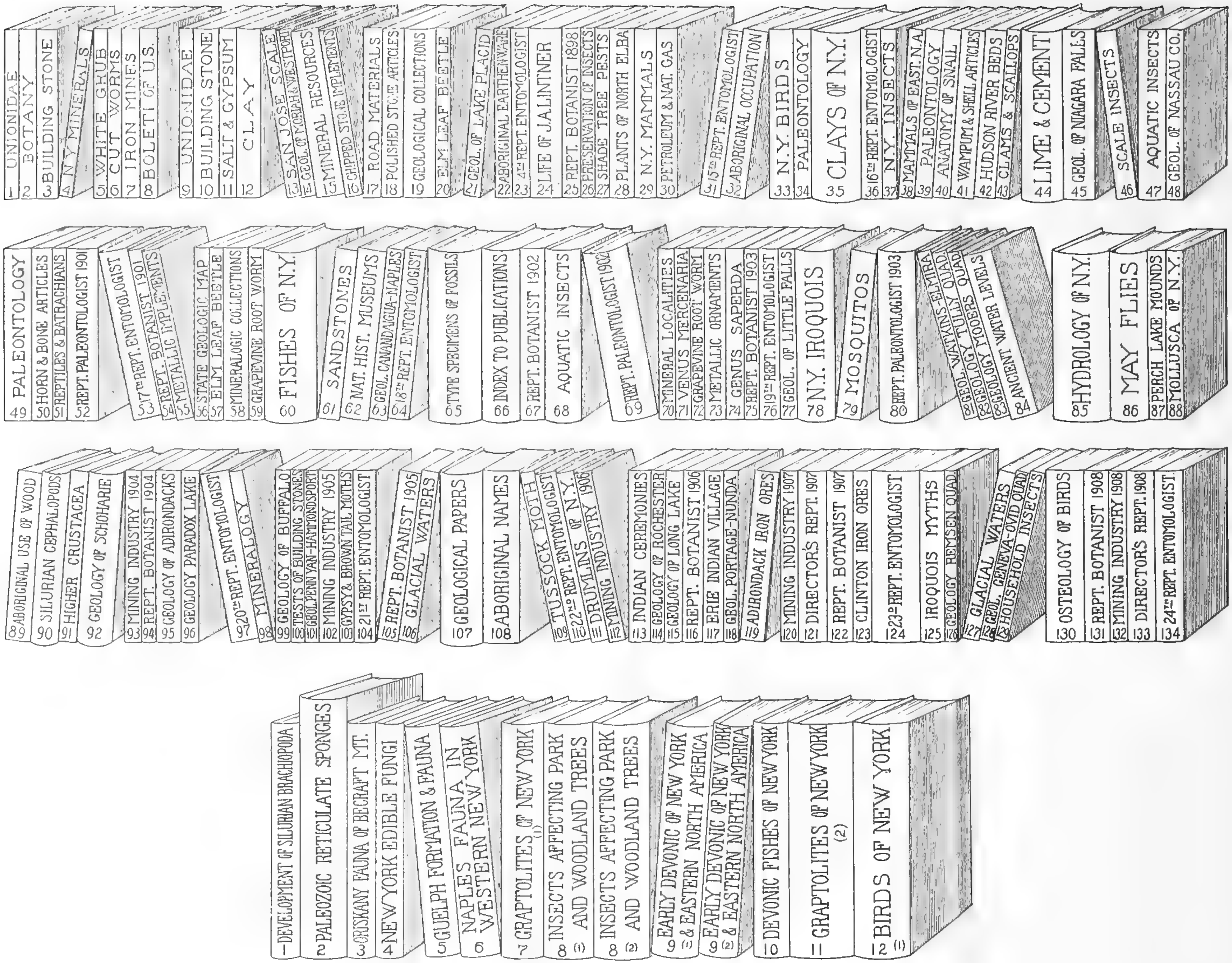
Bulletins

Geology

3 No. 126 Geology of the Remsen Quadrangle. By W. J. Miller. 54p. 11pl. map.

Contents:


1 UNIONIDAE
2 BOTANY
3 BUILDING STONE
4 N.Y. MINERALS
41 WAMPUM & SHELL ARTICLES
42 HUDSON RIVER BEDS
43 CLAMS & SCALLOPS
44 LIME & CEMENT
45 GEOL. OF NIAGARA FALLS
46 SCALE INSECTS
47 AQUATIC INSECTS
48 GEOL. OF NASSAU CO.
49 PALEONTOLOGY
50 HORN & BONE ARTICLES
51 REPTILES & BATRACHIANS
81 GEOL.
82 GEOLOGY TULLY QUAD.
83 GEOLOGY MOOERS QUAD.
84 ANCIENT WATER LEVELS
85 HYDROLOGY OF N.Y.
86 MAY FLIES
87 PERCH LAKE MOUNDS
88 MOLLUSCA OF N.Y.
89 ABORIGINAL USE OF WOOD
90 SILURIAN CEPHALOPODS
91 HIGHER CRUSTACEA
127 GLACIAL WATERS
128 GEOL. GENEVA-OVID QUAD.
129 HOUSEHOLD INSECTS
130 OSTEOLOGY OF BIRDS
131 REPT. BOTANIST 1908
132 MINING INDUSTRY 1908
133 DIRECTOR'S REPT. 1908
134 24TH REPT. ENTOMOLOGIST



Bulletins and memoirs. New York State Museum

1892–1909

4 No. 127 Glacial Waters in Central New York. By H. L. Fairchild. 64p. 27pl. 15 maps.

Contents:

5 No. 132 The Mining and Quarry Industry of New York State. By D. H. Newland. 98p.

Contents:

Paleontology

6 No. 128 Geology of the Geneva-Ovid Quadrangles. By D. Dana Luther. 44p. map.

Contents:

Entomology

7 No. 129 Control of Household Insects. By Ephraim Porter Felt. 48p.

Contents:

8 No. 134 Report of the State Entomologist for the fiscal year ending September 30, 1908. 208p. 17pl.

Contents:

Botany

9 No. 131 Report of the State Botanist for the fiscal year ending September 30, 1908. 202p. 4pl.

Contents:

Zoology

10 No. 130 Osteology of Birds. By R. W. Shufeldt. 382p. 26pl.

Contents:

Archeology

11 No. 125 Myths and Legends of the New York State Iroquois. By Harriet Maxwell Converse. Edited and annotated by Arthur Caswell Parker. 196p. 11pl.

Contents:

Geological maps

12 Remsen Quadrangle
13 Geneva-Ovid Quadrangles

IN PRESS

Memoirs

14 Birds of New York, volume 1
15 Calcites of New York

Bulletins

Geology

16 Geology of the Port Leyden Quadrangle
17 Geology of the Thousand Island Region
18 Geology of the Auburn-Genoa Quadrangles
19 Geology of the Elizabethtown and Port Henry Quadrangles

Entomology

20 Report of the State Entomologist for the fiscal year ending September 30, 1909

Botany

21 Report of the State Botanist for the fiscal year ending September 30, 1909

VIII

STAFF OF THE SCIENCE DIVISION AND STATE MUSEUM

The members of the staff, permanent and temporary, of this division as at present constituted are:

ADMINISTRATION

John M. Clarke, *Director*
Jacob Van Deloo, *Director's clerk*

GEOLOGY AND PALEONTOLOGY

John M. Clarke, *State Geologist and Paleontologist*
David H. Newland, *Assistant State Geologist*
Rudolf Ruedemann Ph.D., *Assistant State Paleontologist*
C. A. Hartnagel B.S. M.A., *Assistant in Geology*
Henry Leighton, *Assistant in Economic Geology*
D. Dana Luther, *Field Geologist*
Herbert P. Whitlock C.E., *Mineralogist*
George S. Barkentin, *Draftsman*
Joseph Morje, *First clerk*
H. C. Wardell, *Preparator*
Paul E. Reynolds, *Stenographer*
Martin Sheehy, *Machinist*
Joseph Bylancik, *Page*

Temporary assistants

Areal geology

Prof. H. P. Cushing, Adelbert College
Prof. J. F. Kemp, Columbia University
Dr C. P. Berkey, Columbia University
Prof. C. E. Gordon, Massachusetts Agricultural College
G. H. Hudson, Plattsburg State Normal School
Prof. W. J. Miller, Hamilton College
Prof. H. O. Whitnall, Colgate University
Burton W. Clark, Washington, D. C.

Geographic geology

Prof. Herman L. Fairchild, Rochester University

Paleontology

Edwin Kirk, Columbia University

BOTANY

Charles H. Peck M.A., *State Botanist*
Stewart H. Burnham, *Assistant,* Glens Falls

ENTOMOLOGY

Ephraim P. Felt B.S. D.Sc., *State Entomologist*
D. B. Young, *Assistant State Entomologist*
Fanny T. Hartman, *Assistant*
Anna M. Tolhurst, *Stenographer*
J. Shafer Bartlett, *Clerk*

ZOOLOGY

Frank H. Ward, *Zoologist*
Alfred J. Klein, *Taxidermist*

Temporary assistants

E. Howard Eaton, Canandaigua
Dr H. A. Pilsbury, Philadelphia
Prof. Philip F. Schneider, Syracuse

ARCHEOLOGY

Arthur C. Parker, *Archeologist*

Temporary assistant

E. R. Burmaster, Irving

IX

ACCESSIONS

ECONOMIC GEOLOGY

Collection

Assistant in Economic Geology

Gypsum, Akron	12
" Camillus	10
" Clockville	2
" Garbutt	26
" Jamesville	4
" Lyndon	6
" Martisco	4
" Oakfield	4
" Phelps	2
" Victor	3
" Wheatland	1

Gypsum mill products	15
Limestone associated with gypsum	4
Clarke, John M.	
Gypsum, Magdalen Islands, Quebec	100
	193

PALEONTOLOGY

Donation

His excellency Governor and Mrs Allardyce. Falkland Islands

The following fossils and minerals from Falkland Islands

Casts of trilobites	4
Miscellaneous fossils	16
Minerals	5

Mansuy, H. Hanoi (Tonkin) Indo-China

Spirifer tonkinensis. Lower Devonic from Ban Lan, French China..	1
Spirifer	1

Schuchert, *Prof.* **Charles**

Graptolites from Point Levis, P. Q., Canada	13
Graptolites from Anticosti island, P. Q., Canada	7

von Koenen, *Prof. Dr* **A.** Göttingen, Germany. Devonic fossils from Martenberg and Enkeberg, Germany

From Martenberg, Germany

Agoniatites inconstans	1
A. inconstans *var.* expansus *Van*	1
A. inconstans *var.* nodosus	1
A. inconstans *var.* obliquus *Whitb*	1
Anarcestes nuculiformis *Holz*	3
Gephyroceras calculiforme	1
G. intumescens	1
Kophinoceras alatum *Holz*	1
Maenoceras terebratum	6
Stringocephalus burtini	2
Tornoceras simplex	1

From Enkeberg

Aganides sulcatus *Münster*	2
Cheiloceras circumplexum *Sand*	1
C. verneuili *Sand*	2
Poterioceras subfusiforme *Wed*	2
Prolobites delphinus *Sand*	1
P. delphinus *var.* atava *Frech*	1
P. delphinus *var.* ellipticum *Wed*	1
Sporadoceras angustisellatum *Wed*	3
S. münsteri *von Buch*	9
Tornoceras rotundodorsatum *Wed*	3
T. sandbergeri	3

Wilson, John D. Syracuse, N. Y.

Thoracoceras wilsoni *Clarke*	1

Purchase

Wilson, John D. Syracuse, N. Y.

Tully limestone	
Brachiopods	12
Gastropods	1
Cephalopods	1
Hamilton	
Corals	6
Brachiopods	16
Gastropods	27
Lamellibranchs	38
Cephalopods	2
Trilobites	10
Agoniatite limestone	
Brachiopods	10
Cephalopods	57
Onondaga limestone	
Gastropods	27
Cephalopods	3
Trilobites	1
Cambric	
Trilobites	2
Total	213

Collection

Assistant State Paleontologist. Graptolites from Lower Siluric shales of Saratoga county 216

Clarke, John M.

Carboniferous fossils, Magdalen Islands, Quebec .... bbls. 4

Geological specimens, Magdalen Islands, Quebec 50

Cushing, *Prof.* **H. P., Ruedemann, R. & Miller,** *Prof.* **W. J.** Fossils, mostly trilobites, from the Saratogan (Hoyt's quarry), Saratoga co. 400

Fossils from Beekmantown limestone of Mohawk valley 31

Fossils from Trenton limestone, Saratoga co 32

Hartnagel, C. A. Eurypterids from Bertie waterlime, Herkimer co. 30

Hartnagel, C. A. & Van Deloo, Jacob. Eurypterids from Bertie waterlime, Herkimer co 500

Luther, D. D. Crinoids from Grimes sandstone near Naples 20

Crinoids and starfishes from Grimes sandstone, Italy Hollow gully, near Naples, N. Y .... boxes 5

Crinoids from Hamilton formation near West Alden, Erie co 8

Wardell, H. C. Graptolites from Rural Cemetery, Albany 25

Oriskany fossils from Glenerie, Ulster co 500

MINERALOGY

Donation

Kelley, F. W. Albany
Calcite in limestone, Howe Cave 2

Magill, C. M. Albany
Geode containing goethite, Keokuk, Iowa 1

Ross, J. McCormick, S. C.
Psilomelane and barite replacing asbestos, McCormick, S. C 1
Serpentine (asbestos), McCormack, S. C 1
Psilomelane, McCormick, S. C 12
Barite on psilomelane 8

Moore, E. L. Port Byron, N. Y.
Vesuvianite and epidote, Fassathal, Tyrol 1
Fluorite, Cumberland, Eng 1
Pyrite and chalcopyrite, Colorado (?) 1
Tourmalin, Paris, Me 2

Snyder, W. S. Watervliet
Calcite and sphalerite, Arizona 5

Exchange

Canfield, F. A. Dover, N. J.
Pyrite on calcite, Bergen Hill, N. J 1
Stilbite on datolite, Bergen Hill, N. J 1
Apophyllite, analcite and atolite, Bergen Hill, N. J 1
Natrolite and apophyllite, Bergen Hill, N. J 1
Natrolite and datolite, Bergen Hill, N. J 1

Manchester, J. G. New York
Calcite and datolite, Bergen Hill, N. J 10
Calcite and apophyllite, Bergen Hill, N. J 4
Apophyllite and datolite, Bergen Hill, N. J 3
Apophyllite and natrolite, Bergen Hill, N. J 2
Apophyllite and analcite, Bergen Hill, N. J 3
Apophyllite and calcite, Bergen Hill, N. J 1
Apophyllite, Bergen Hill, N. J 9
Apophyllite on stilbite, Bergen Hill, N. J 1
Analcite on calcite, Bergen Hill, N. J 1
Natrolite, Bergen Hill, N. J 3
Datolite, Bergen Hill, N. J 5
Stilbite on datolite, Bergen Hill, N. J 1
Chalcopyrite on datolite, Bergen Hill, N. J 1
Chalcopyrite on calcite, Bergen Hill, N. J 1
Sphalerite on stilbite (large), Bergen Hill, N. J 1
Sphalerite and datolite, Bergen Hill, N. J 1
Calcite, Bergen Hill, N. J 1

Foote Mineral Co. Philadelphia, Pa.
Pyrite, Bingham, Utah 4
Pyrite and tetrahedrite, Bingham, Utah 1
Tetrahedrite, Bingham, Utah 1

Pentlandite, Sudbury, Ontario 1
Sphalerite, Kokomo, Col 1
Covellite, Summitville, Col 1
Opal (opalized wood), Clover Creek, Idaho 1
Wollastonite, Blount Mt, Tex 1
Natrochalcite, Chuquicamata, Chili 1
Kröhnkite, Chuquicamata, Chili 1
Brochantite, Chuquicamata, Chili 1
Orthoclase (valencianite), Guanajuato, Mex 1
Quartz (twin crystal), Guanajuato, Mex 1
Nadorite, Djebel-Nador, Algeria 1
Chabazite, Melbourne, Victoria 1
Newberryite, near Ballarat, Victoria 48
Amblygonite, Port Darwin, S. Aust 1
Anglesite on cerussite, Broken Hill, N. S. W 1
Cabrerite, Laurium, Greece 1

Peck, H. C. Albany.

Zoisite, Chester, Mass 1
Octahedrite, Somerville, Mass 1

Purchase

Comptoir Mineralogique Suisse, Geneva, Switz.

Phenacite, San Miguel do Piracicava, Minas Geraes, Brazil 1

Hodge, R. S. Antwerp

Millerite on hematite, Antwerp 60
Hematite (botryoidal), Antwerp 6
Hematite (specular) on quartz, Antwerp 11
Hematite (stalactitic), Antwerp 5
Chalcopyrite on quartz, Antwerp 2
Pyrite and calcite, Antwerp 1
Pyrite and ankerite, Antwerp 2
Calcite on hematite, Antwerp 9
Calcite and dolomite, Antwerp 1
Calcite on chalcodite (large), Antwerp 1
Dolomite and ankerite, Antwerp 5
Dolomite (stalactitic), Antwerp 1
Ankerite on hematite, Antwerp 9
Ankerite (stalactitic), Antwerp 8
Ankerite on quartz, Antwerp 10
Quartz (drusy stalactite), Antwerp 2
Quartz on hematite, Antwerp 20
Chalcodite on stalactitic quartz, Antwerp 5
Chalcodite on quartz, Antwerp 3
Chalcodite on calcite, Antwerp 3
Chalcodite on hematite, Antwerp 6
Chalcodite and ankerite, Antwerp 6
Goethite on ankerite and quartz, Antwerp 1
Fluorite, Macomb 3
Quartz in matrix, Little Falls 1

Tourmalin, Gouverneur	1
Quartz, Ellenville	1
Fluorite, Cumberland, Eng	5
Siderite on fluorite, Cumberland, Eng	2
Pyrite, England	2
Barite, Cumberland, Eng	1
Apatite, Norway	1
Psilomelane, Sevilla, Spain	1
Sulfur and calcite, Girgenti, Sicily	1
Cryolite, Greenland	1
Apophyllite, Guanajuato, Mex	1
Apatite, Renfrew co., Ontario, Can	1
Stilbite, Partridge Island, N. S	3
Heulandite, Nova Scotia	2
Chabazite, Nova Scotia	1
Hematite, Lake Superior	1
Albite (cleavelandite), Auburn, Me	1
Lepidolite, Auburn, Me	1
Vesuvianite in epidote, Minot, Me	1
Spodumene, Peru, Me	1
Cancrinite, Litchfield, Me	1
Zircon, Litchfield, Me	1
Orthoclase, Maine	1
Garnet, Russell, Mass	1
Margarite, Chester, Mass	1
Andalusite (chiastolite), Lancaster, Mass	1
Cyanite, Norwich, Conn	1
Diabantite, Farmington, Conn	1
Pyrolusite and limonite, Ore Hill, Conn	1
Tourmalin, Haddam, Conn	1
Wernerite, Connecticut	1
Willemite, Franklin, N. J	1
Franklinite, Franklin, N. J	1
Pyrite, French Creek, Pa	8
Chalcopyrite, French Creek, Pa	2
Cyanite, Delaware co., Pa	1
Garnet, Delaware co., Pa	1
Laumontite, Frankford, Pa	1
Pyromorphite, Phoenix, Pa	1
Limonite, Ebbville, Md	1
Pyrophyllite, Chesterfield co., S. C	1
Talc (steatite), Mantahala, N. C	1
Rutile, Graves Mt, Ga	1
Quartz, Crystal Mt, Ark	1
Quartz, Hot Springs, Ark	1
Wavellite, Garland co., Ark	1
Sphalerite, Joplin, Mo	1
Marcasite on sphalerite, Joplin Mo	1
Gypsum, Mahoning co., O	1
Quartz (geode), Warsaw, Ill	9

Microcline (amazon stone), Pikes Peak, Col	2
Halite, Lincoln co., Nev	1
Proustite and stephanite, Lander co., Nev	1
Wulfenite, Nevada	1
Galena, Utah	1
Cinnabar, New India, Col	1
Gold in quartz, California	1
Tetrahedrite, California	1
Quartz (geyserite), Yellowstone Park, Wyo	1
Wulfenite, Yuma co., Ariz	1
Azurite and malachite, Bisbee, Ariz	1
Malachite, Bisbee, Ariz	1
Chrysocolla, Loc. ?	1
Calamine, Loc. ?	1
Beryl (large), Loc. ?	1
Quartz & chalcedony, Loc. ?	1
Quartz (large), Loc. ?	2
Vivianite, Loc. ?	1

Collection

Assistant in Economic Geology

Gypsum, Garbutt	15

Mineralogist

Serpentine pseudomorph after garnet (loose crystals), Saratoga	15
Serpentine pseudomorph after garnet in matrix (large), Saratoga	8
Serpentine pseudomorph after garnet in matrix (small), Saratoga	10
Garnet in gneiss, Saratoga	4
	488

BOTANY

Plants added to the herbarium

New to the herbarium

Ascochyta solani-nigri *Diedicke*
Belonidium glyceriae *Pk.*
Biatora cupreo-rosella (*Nyl.*) *Tuck.*
Bidens tenuisecta *Gray*
Boletus viridarius *Frost*
Carduus crispus *L.*
Chaenactis stevioides *H. & A.*
Ciboria luteo-virescens *R. & D.*
Clitocybe candida *Bres.*
Cortinarius subsalmoneus *Kauff.*
Crataegus brevipes *Pk.*
C. efferata *S.*
C. letchworthiana *S.*
Diplocladium penicilloides *Sacc.*
Diplodia cercidis *E. & E.*
D. hamamelidis *Fairm.*
D. tamariscina *Sacc.*
Dothiorella divergens *Pk*
Epipactis tesselata (*Lodd.*) *Eaton*
Fenestella amorpha *E. & E.*
Hypholoma boughtoni *Pk.*
H. rigidipes *Pk.*
Leontodon nudicaulis (*L.*) *Banks*
Ligusticum scoticum *L.*
Lophiotrema hysterioides *E. & E.*
L. littorale *Speg.*
Marasmius alienus *Pk.*
Melanopsamma confertissima (*Plowr.*)
Microcera coccophila *Desm.*

Midotis irregularis (*Schw.*) *Cke.*
Monolepis nuttalliana (*R. & S.*)
Morchella crispa *Karst.*
M. rimosipes *DC.*
Nardia crenulata (*Sw.*) *Lindb.*
N. hyalina (*Lyell*) *Carr.*
Peridermium strobi *Kleb.*
Pezizella lanc.-paraphysata *Rehm*
Phaeopezia fuscocarpa (*E. & H.*)
Pholiota aurivella *Batsch*
Phomopsis stewartii *Pk.*
Picris echinoides *L.*
Polyporus giganteus (*Pers.*) *Fr.*
Psilocybe nigrella *Pk.*
Puccinia epiphylla (*L.*) *Wettst.*
Ribes triste albinervium (*Mx.*)
Rubia tinctorium *L.*
Rumex pallidus *Bigel.*
Schwalbea americana *L.*
Septoria sedicola *Pk.*
Solidago aspera *Ait.*
Sparganium diversifolium *Graebn.*
Stachys sieboldii *Miq.*
Stephanoma strigosum *Wallr.*
Trametes merisma *Pk.*
Verticillium rexianum *Sacc.*
Volvaria volvacea (*Bull.*) *Fr.*

ENTOMOLOGY

Donation

Hymenoptera

Cockerell, T. D. A. Boulder, Col. Sphecodes fragariae Ckll., S. sophiae Ckll. var. Halictus scrophularia Ckll., Augochlora neglectula Ckll., Andrena prunorum gilletti Ckll., Panarginus cressoniellus Ckll., February 16

Rohwer, S. A. Boulder, Col. Steniolia obliqua Say, Trypoxylon frigidum Sm., Thyreopus latipes Sm. Andrena geranii Rob., A. porterae Ckll., A. prunorum Ckll., Nomada collinsiana Ckll., Osmia fulgida Cress., Dianthidium parvum Cress., Megachile pugnata Say, Ceratina neomexicana Ckll., Melissodes obliqua Say, M. agilis Cress., Anthophora simillima Cress., November 12

Batly, *Miss* **M. A.** Schaghticoke. Xylocopa virginica Dru., large carpenter bee, adult, June 28

Doubleday, Page & Co. New York. Agapostemum viridula Fabr., solitary digger bee, adult, from Rutland, Vt., July 9

Patterson, O. D. Richburg. Thalessa atrata Fabr., black long sting, adult, June 24

Hasbrouck, *Miss* **L. M.** Ogdensburg. Rhodites rosae Linn., rose bedegar, gall on rose, July 10

Frost, H. L. & Co. White Plains. Andricus clavula Bass., oak tip gall on white oak, October 23

Goldmark, *Miss* **Josephine.** St Huberts. Lophyrus lecontei Fitch, pine sawfly, larvae on pine, July 31

Huested, Percy L. Rochester. Emphytus cinctus Linn., coiled rose slug, larva on rose, January 30

Thomson, J. A. Rochester. Amauronematus azaleae Marlt., larvae on azalea, June 8

Livingston, J. H. Tivoli. Kaliosysphinga ulmi Sund., elm leaf miner, larvae on elm, June 7

Thomson, J. A. Rochester. Same as preceding, June 17

Thompson, *Miss* **Rhoda.** Ballston Spa. Lygaeonematus erichsonii Hart., larch sawfly, larvae on larch, June 28

Hoover, D. D. Syracuse. Tremex columba Linn., pigeon Tremex, adult, September 13

Closson, R. Addison. Same as preceding, adult on maple, September 22

Coleoptera

Forest, Fish & Game Commission. Hylesinus aculeatus Say, ash bark beetle, adults, eggs and larvae on ash, from Cornwall, May 18

Levison, J. J. Brooklyn. Eccoptogaster quadrispinosus Say, hickory bark borer, larvae on hickory, October 28

Hoover, D. D. Syracuse. Eccoptogaster rugulosus Ratz., hickory bark borer, adult and larvae on hickory, September 17

Roach, Paul. Quaker Street. Pomphopoea sayi Lec., Say's blister beetle, adults on rose, June 28

Niles, T. F. State Department of Agriculture. Epicauta ? puncticollis Mann., blister beetle, adults, from Chatham, July 24

Norris, E. B. Sodus. Disonycha pennsylvanica Ill., adult on apple trees, March 31

Zabriskie, George. Nissequogue, St James, L. I. Galerucella luteola Mull., elm leaf beetle, larvae on elm, July 12

Forest, Fish & Game Commission. Same as preceding, from Greenport, July 8

Fish, J. H. Greenport. Same as preceding, July 14

Delafield, *Mrs* **Albert.** Greenport. Larvae and pupae of preceding, August 18

McKensie, P. B. Northport. Same as preceding, July 23

VanClefe, John O. Oakdale. Same as preceding, July 26

White, E. M. Sag Harbor. Same as preceding, August 5

Simpson, C. L. Amsterdam. Same as preceding, August 24

Miller, *Mrs* **W. S.** Boonville. Trichius affinis Gory, adult, July 15

Chatfield, Frederick. Troy. Euphoria inda Linn., flower beetle, adults, September 21

Schaible, G. C. Brooklyn. Macrodactylus subspinosus Fabr., rose beetle, adults, June 19

Lindquist, F. Brooklyn. Same as preceding, June 21

Blunt, *Miss* **Eliza S.** New Russia. Chalcophora liberta Germ., smaller flat-headed pine borer, adult, June 3

Country Gentleman. Phengodes plumosa Oliv., larva, from Ridgefield, Conn., August 9

Nash, C. W. Toronto, Can. Asaphes decoloratus Say, larvae killed by a fungus, Cordyceps acicularis Rav. (C. carolinensis B. & R., Ravenel's *Exsiccati*) November 27

Patterson, *Mrs* **J. D.** Pattersonville. Alaus oculatus Linn., owl beetle or eyed elater, adult, June 23

Hepworth, J. A. Marlborough. Silvanus surinamensis Linn., saw-toothed grain beetle, adult in flour, April 20

Winchester, Milo F. South Amenia. Anatis ocellata Linn., larva, pupa and adult on apple, July 1

Ferris, S. B. Upper Saranac. Nomius pygmaeus Dej., August 21

Diptera

Brisbin, C. E. Schuylerville. Rhagoletis pomonella Walsh, many adults on apple; R. suavis Loew, adult on apple, September 10

Baldwin, L. F. Albany. Bombyliomyia abrupta Wied., adult, August 25

Clarke, *Miss* **Cora H.** Numerous Cecidomyiid galls were received from Boston and Magnolia, Mass. and a number of new species reared from the material contributed. [*See* Econ. Ent. Jour. 1909, 2:286–93]

Alexander, C. P. Johnstown. A number of Cecidomyiids were received during the season.

Dimmock *Dr* **George.** Springfield, Mass. Rhopalomyia hirtipes O. S., numerous subterranean galls on Solidago, September 2

Packard, Winthrop. Canton, Mass. Sackenomyia packardi Felt, larvae in willow shoots, April 15

Webster, F. M. Washington, D. C. Lasioptera tripsaci Felt, adults reared from Tripsacum dactyloides, from Texas

Nash, George V. Bronx Park, New York. Cecidomyia opuntiae Felt, reared from Opuntia leaves

A number of other gall midges have been received from various parties and will be duly acknowledged in subsequent descriptions or discussions of the species.

Lepidoptera

Call, *Miss* **Emma S.** Northport. Sphecodina abbotii Swain, Abbot's sphinx, larvae on woodbine, July 30

Openhym, *Mrs* **A.** St Huberts. Same as preceding, August 12

Bell & Smith Nursery Seed Co. Castleton. Deilephila lineata Fabr., white lined sphinx, moth, September 11

Shults, Ezra. Fort Plain. Sphinx drupiferarum Sm. & Abb., plum sphinx, adult, June 7

Fitch, H. H. West Winfield. Sphinx chersis Hubn., ash sphinx, adult, July 26

Delafield, *Mrs* **Albert.** Greenport. Halisidota caryae Harr. on elm, August 18

Slade, George P. New York city. Heliophila unipuncta Haw., army worm, larvae, from Oakdale, June 17

Frispell, *Dr* **C. W.** Shelter Island Heights. Heliothis armiger Hubn., corn worm, larvae on corn, October 19

Baxter, Jarvis W. Adams Corners. Melalopha inclusa Hubn., poplar tentmaker, larvae on poplar, August 2

Dillingham, E. Ogdensburg. Notolophus antiqua Linn., dark or rusty tussock moth, larvae, June 29

Burbank, Charles. LaGrangeville. Tolype velleda Stoll., larch lappet, larva, July 23

Emans, Ernest. LaGrangeville. Paleacrita vernata Peck, spring canker worm, larvae on apple trees, May 31

Floyd, Augustus. Moriches. Alsophila pometaria Harr., fall canker worm, adults, November 30 and December 2

Jackson, *Mrs* **A. M. A.** Warner. Acrobasis larvae on hickory, June 12

Huested, P. L. Blauvelt. Archips cerasivorana Fitch, ugly nest cherry worm, nest, July 17

Bailey, G. A. Syracuse. Tortrix fumiferana Clem., spruce bud worm, adults, July 21

Lohrmann, Richard. Utica. Same as preceding, July 22

Fitch, F. A. Randolph. Coleophora fletcherella Fern., cigar case bearer, larvae on apple, June 16

VanClefe, John O. Oakdale. Coleophora limosipennella Dup., European elm case bearer, cases and adults, August 4

Latham, Roy. Orient Point. Antispila nyssaefoliella Clem., larvae and work on pepperidge, September 25

Corrodentia

Burnham, S. H. Vaughn. Psocus salicis? Fitch, nymph in house, November 4

Hemiptera

Cook, Paul. Troy. Enchenopa binotata Say, 2-spotted tree hopper, egg masses on bittersweet, August 25

Gillett, J. R. Kingston. Belostoma americanum Leidy, electric light bug, adult, October 26

Thomson, J. A. Rochester. Leptobyrsa explanata Heid., lace-winged bug, larvae on Rhododendron, June 8

Huested, P. L. Blauvelt. Same as preceding, adult, July 5

O'Mara, J. F. Cornwall. Aleyrodes citri Riley & Howard, white fly on orange leaf, from Florida, June 15

Livingston, J. H. Tivoli. Phyllaphis fagi Linn., woolly beech leaf aphis, adults on beech, May 15

Huested, P. L. Blauvelt. Chermes strobilobius Kalt., spruce gall aphid, galls on spruce, May 3

Ray, *Mrs* **George W.** Norwich. Chermes pinicorticis Fitch, pine bark aphid, adults on pine, March 30

Breithaupt, E. & W. G. Phoenicia. Same as preceding, adults and eggs on balsam, September 11

Livingston, J. H. Tivoli. Adults of preceding on pine, September 14

May, William B. Irvington. Chermes abietis Linn., spruce gall aphid, galls on spruce, March 8

Pettis, C. R. Lake Clear Junction. Same as preceding, August 14

Witherbee, F. S. Port Henry. Phylloxera caryaecaulis Fitch, hickory gall aphid, adults and young on hickory, June 30

Ackley, Henry. Cambridge. Pemphigus vagabundus Walsh, galls on poplar, July 30

McCulloch, C. H. Schenectady. Same as preceding, August 11.

Ackley, Henry. Cambridge. Pemphigus populi-transversus Riley, galls on poplar, July 30

Donan, W. C. LeRoy. Colopha ulmicola Fitch, cockscomb elm gall on elm, July 19

Niles, H. W. State Department of Agriculture. Schizoneura americana Riley, woolly elm leaf aphid, adults on elm, from Rye, July 6

Graves, *Mrs* **H. D.** Ausable Forks. Same as preceding, June 25

Foulk, Theodore. Flushing. Lachnus dentatus LeBaron, adult on willow, September 23

Jones, H. G. Dunkirk. Callipterus ulmifolii Monell, elm leaf aphid, badly infested leaves of elm, June 29

Thomson, J. A. Rochester. Psyllid, June 17

Menand, L. Albany. Chrysomphalus dictyospermi Morg., Morgan's scale, all stages, abundant and causing serious damage on palm, December 28

Livingston, J. H. Tivoli. Eulecanium tulipiferae Cook, tulip tree scale, adults on tulip, September 14

VanAlstyne, H. Chatham Center. Coccus hesperidum Linn., soft scale, young and adults on begonia, December 12

Dummett, Arthur. Mt Vernon. Phenacoccus acericola King, false maple scale, young on maple, November 10

Thomson, J. A. Rochester. Pulvinaria vitis Linn., cottony maple scale, adults on maple, June 21

Huested, P. L. Blauvelt. Gossyparia spuria Modeer, elm bark louse, adult on elm, from Catskill, June 21

Foley, *Miss* **Frances.** Cornwall. Aulacaspis rosae Sandbg., rose scale, eggs on blackberry, April 22

Niles, T. F. State Department of Agriculture. Aulacaspis pentagona Targ., West Indian peach scale on Prunus pseudocerasus, from New Rochelle

Gibson, Arthur. Ottawa, Can. Chionaspis pinifoliae Fitch, pine leaf scale on spruce, January 5

Foulk, Theodore. Flushing. Same as preceding, on Austrian pine, September 11

Richmond, Charles A. East Aurora. Aspidiotus forbesi John., on apple, November 6

Cunningham, Thomas. Vancouver, B. C. Aspidiotus ostreaeformis Curt. on apple, pear and plum, October 29

Burt, A. C. Owego. Aspidiotus perniciosus Comst., San José scale, adults on apple, April 10

Smith, A. J. Rexford Flats. Same as preceding, June 1

Windsor, *Mrs* **P. L.** Austin, Tex. Very kindly determined by E. P. VanDuzee, Buffalo. Draeculacephala reticulata Sign., Deltocephalus sonorus Ball, D. flavicosta Stal., D. nigrifrons Forbes, D. obtectus O. & B., D. inimicus Say, Xestocephalus pulicarius VanD., X. brunneus VanD., Eutettix strobi Fitch, E. stricta Ball, Acinopterus acuminatus VanD., Phlepsius spatulatus VanD., Athysanus exitiosus Uhler, Platymetopius near loricatus VanD., Scaphoideus consors Uhler, typical, S. immistus Say, Typhlocyba vulnerata Fitch, T. comes Say, T. sp. (near trifasciata), T. comes var. vitis Harr., T. tri-

cincta Fitch, Oliarus complectus Ball, Pissonotus delicatus VanD., P. basalis VanD., ater Van. D. ?, Liburnia pellucida Fabr. ?, L. consimilis VanD., Empoasca mali LeBaron, E. flavescens Fabr., E. sp. new, Balclutha abdominalis VanD. ?, Nysius minutus Uhler, Reuteroscopus ornatus Reut., Atomoscelis seriatus Reut. ?

Orthoptera

Appleby, Lansing. Clarksville. Oecanthus niveus DeG., snowy tree cricket, eggs on raspberry, April 3

Thompson, J. A. Syracuse. Periplaneta americana Linn., American cockroach, adult, April 10

Adams, Louis H. Canandaigua. Mantis religiosa Linn., European Mantis, egg mass, February 15

Thysanura

Jackson & Perkins. Newark. Achorutes nivicola? Fitch, very abundant on sand, April 8

Isoptera

VanDenburg, M. W. Mt Vernon. Termes flavipes Linn., white ants, adults, April 19

Exchange

Hymenoptera

Tucker, E. S. Manhattan, Kan. Trypoxylon carinifrons Fox, Polistes minor Beauv.

Coleoptera

Berosus subsignatus Lec., Psyllobora taedata Lec., Conotelus stenoides Murr., Scaptolenus lecontei Salle, Photinus benignus Lec. Lobetus abdominalis Lec.

Diptera

Beskia aelops Walk., Sturmia distincta Wied., Sarcophaga assidua Walk., S. quadrisetosa Coq., Pseudopyrellia comicina Fabr., Pachycerina clavipennis Coq.

Lepidoptera

Chlorochlamys phyllinaria Zell., Loxostege mancalis Led., Lineodes integra Zell., Crambus teterrellus Zink., C. mutabilis Clem., Saluria tetradella Zell., Pterophorus inquinatus Zell., Platynota nigrocervina Wals., Anaphora popeanella Clem.

Purchase

Kny-Scheerer Co. New York city

House fly, Musca domestica Linn. (x 30), model

Malarial mosquito, Anopheles, dissectible model of head (x 800)

House mosquito, Culex pipiens Linn., dissectible model of head (x 800)

ZOOLOGY

Donation

Mammals

Alexander, Charles P. Johnstown. Say's bat, Myotis subulatus (Say), skin 1
Baumer, J. H. Cedar Hill. Virginia deer, Odocoileus virginianus (Boddaert), fossil skull 1
Scace, William. Schenectady road. Otter, Lutra canadensis Schreber, juv. skins 2
Woodruff, E. S. Albany. Raccoon, Procyon lotor (Linn.), skull 1

Birds

Alexander, Charles P. Johnstown
White-winged crossbill, Loxia leucoptera Gmel., skins 3
Redpoll, Acanthis linaria (Linn.), skin 1
Pine siskin, Spinus pinus (Wilson), skins 2
Nashville warbler, Vermivora rubricapilla (Wils.), skin 1
Yellow warbler, Dendroica aestiva (Gmel.), skin 1
Black-throated blue warbler, Dendroica caerulescens (Gmel.), skin 1
Chestnut-sided warbler, Dendroica pennsylvanica (Linn.), skin 1
Pine warbler, Dendroica vigorsii (Aud.), skin 1
Mourning warbler, Oporornis philadelphia (Wils.), skin 1
Maryland yellowthroat, Geothlypis trichas (Linn.), skin 1
Wilson's warbler, Wilsonia pusilla (Wis.), skin 1
Canadian warbler, Wilsonia canadensis (Linn.), skin 1
Delavan, *Dr* E. H. Round Lake. Four-legged chicken, spec 1
Drumm, Jimmy. Albany. Canary, Carduelis canaria (Linn.), skin 1
Friend, William. New Baltimore. Turkey vulture, Cathartes aura septentrionalis (Wied.), skin 1
Forest, Fish & Game Commission. Albany. Wood duck, Aix sponsa (Linn.), skin 1
Hall, Charles. Albany
American goshawk, Astur atricapillus (Wilson), skin 1
Red-shouldered hawk, Buteo lineatus (Gmel.), skin 1
Helm, Harry. Sharon Springs. Four-legged chicken, spec 1
Klein, A. J. Albany
Water turkey, Anhinga anhinga (Linn.), skin 1
Florida cormorant, Phalacrocorax auritus floridanus (Aud.), skins 2
Red-shouldered hawk, Buteo lineatus (Gmel.), skin 1
Barred owl, Strix varia Barton, skin 1
Short-eared owl, Asio flammeus (Pontop.), skins 3
Leighton, Henry. Albany
Redpoll, Acanthis linaria (Linn.), skin 1
Pine siskin, Spinus pinus (Wils.), skin 1

Parker, A. C. Albany
Phoebe, Sayornis phoebe (Lath.), eggs.......... 4
Fish crow, Corvus ossifragus Wils., egg.......... 1
Red-winged blackbird, Agelaius phoenicius (Linn.), eggs.. 4
Bullock's oriole, Icterus bullocki (Swains.), eggs.......... 6
Red-eyed vireo, Vireosylva olivacea (Linn.), eggs.......... 4
Maryland yellowthroat, Geothlypis trichas (Linn.), eggs..... 3
Long-billed marsh wren, Telmatodytes palustris (Wils.), eggs 2
Woodthrush, Hylocichla mustelina (Gmel.), eggs.......... 4

Fishes

Bean, *Dr* **Tarleton H.** Albany
White bass, Roccus chrysops (Raf.), spec.......... 3
New York Aquarium. New York
Drum, Pogonias cromis (Linn.), spec.......... 1
Sunfish, Eupomotis gibbosus (Linn.), spec.......... 5
Perch, Perca flavescens (Mitchill), spec.......... 5
Pearl roach, Abramis crysoleucas roseus Bean, spec..... 5

Reptiles

Klein, A. J. Albany. Python, Python sebae Gmel., skull... 1

Batrachians

McCann, *Mr.* Albany. Bullfrog, Rana catesbiana Shaw, spec. 2

Crustacea

Alexander, Charles P. Johnstown
Oniscus asellus Linn., spec.......... 1
Cyclisticus convexus (De Greer), spec.......... 1
Metaponorthus pruinosus (Brandt), spec.......... 2
Anonymous. Limulus polyphemus Linn.......... 1

Arachnida

Alexander, Charles P. Johnstown
Prothesima ecclessiastica (Hentz), spec.......... 1
Gnaphosa conspersa Thorell, spec.......... 1
Clubiona rubra Keys., spec.......... 1
Theridium frondeum Hentz, spec.......... 1
Steatodes borealis (Hentz), spec.......... 1
Lyniphia insignis Blackw., spec.......... 1
L. mandibulata Em.......... 1
L. phrygiana Koch., spec.......... 1
Epeira decipiens Fitch, spec.......... 3
E. parvula Keys., spec.......... 1
E. sclopetaria (Clerck), spec.......... 2
E. stellata (Walck.), spec.......... 2
E. trifolium Hentz, spec.......... 4
E. trivittata Keys., spec.......... 2
Argyroepeira hortorum (Hentz), spec.......... 3

Microepeira radiosa (McCook), spec 1
Xysticus gulosus Keys., spec 1
X. quadrilineatus Keys., spec 1
X. stomachosus Keys., spec 1
X. triguttatus Keys., spec 2
Coriarachne versicolor Keys., spec 1
Misumena vatia (Clerck), spec 4
Runcinia aleatorius (Hentz), spec 1
Tibellus duttoni (Hentz), spec 1
Philodromus rufus Walck., spec 1
Lycosa communis Em., spec 1
L. ocreata Hentz, spec 1
Pirata montanus Em., spec 1
Pardosa pallida Em., spec 1
Dolomedes tenebrosus, Hentz, spec 1
Philaeus princeps (Peckham), spec 1
Eris octavus Hentz, spec 2
Epiblemun scenicum (Clerck), spec 3
Chelifer muricatus Say, spec 1

Myriapoda

Alexander, Charles P. Johnstown
Linotaenia fulva Say, spec 1
Lithobius forficatus Linn., spec 1
Spirobolus marginatus Say, spec 1

Mollusca

Alexander, Charles P. Johnstown
Succinea obliqua totteriana Lea, spec 1
Cochlicopa lubrica (Müller) spec 1
Baldwin, L. F. Albany
Limax maximus Linn., spec 1
Clarke, *Dr* **John M.** Albany
Oleacina truncata Gmel., spec 1
Zonites algirus Linn., spec 1
Pyramidula perspectiva, Say, spec 16
P. rotundata Müller, spec 2
Polygyra clausa Say, spec 2
P. exoleta Binney, spec 2
P. profunda Say, spec 2
P. thyroides Say, spec 2
Acavus haemastoma (Linn.), spec 1
Amphidromus perversus (Linn.), spec 1
Zaphysema macmurrayi C. B. Adams, spec 2
Sagda alveare Pfr., spec 6
S. jayana C. B. Adams, spec 6
Pleurodonte jamaicensis (Gmel.), spec 2
Leucochroa candidissima (Drap.), spec 2

Camaena cicatrosa (Müller), spec	1
Helicella ericetorum (Müller), spec	1
H. caespitum Drap., spec	2
Hygromia rufescens (Penn.), spec	2
Helicigona arbustorum (Linn.), spec	2
H. lapicida (Linn.), spec	2
Helix aspersa Müller, spec	1
H. leucorum castanea Olive., spec	1
H. ligata gussoneana Sh., spec	2
H. nemoralis Linn., spec	3
H. pisana Müller, spec	3
H. pomatia Linn., spec	2
H. vermiculata Müller, spec	2
Bulimus species, spec	1
Archachetina camerunensis (d'Ailly), spec	1
Rumina decollata (Linn.), spec	4
Planorbis corneus (Linn.), spec	1
Ampularia corrugata Swains., spec	2
A. fasciata Linn., spec	1
Paludina lecythoides Benson, spec	1
Adamsiella variabilis (Adams), spec	1
Lucidella aureola (Fer.), spec	1
Helicina costata Gray, spec	2
H. major Gray, spec	1
H. neritella Lam., spec	1

Purchase

Mammals

Elliott, Joseph. Beaver River
Porcupine, Erethizon dorsatus (Linn.), skins 4
Klein, A. J. Albany
Gray fox, Urocyon cinereoargenteus (Schreber), skin 1
Ward's Natural Science Establishment. Rochester
Moose, Alces americanus Jardine, group of mounted specimens 3

Birds

Acker, C. F. Conesus Lake
Double-crested cormorant, Phalacrocorax auritus (Less.) mounted specimen 1
Gowie, W. D. East Greenbush
American bittern, Botaurus lentiginosus (Montag.), skin 1
White, Peter. Albany
Short-eared owl, Asio flammeus (Pontop.), skin 1

Fish

Sea robin, Prionotus carolinus (Linn.), spec 1

Collection

Mammals

Virginia deer, Odocoileus virginanus borealis Miller, skins	2
Cottontail, Sylvilagus transitionalis (Bangs), skins	1
Porcupine, Erethizon dorsatus (Linn.), skin	1
Brown rat, Mus norvegicus Erxleben, skins	5
Woodchuck, Arctomys monax (Linn.), skins	2
Chipmunk, Tamias striata lysteri (Rich.). skins	2
Common mole, Scalops aquaticus (Linn.), skin	1
Large brown bat, Vespertilio fuscus Beauvois, skin	1
Red bat, Laziurus borealis (Müller), skins	2

Birds

Green heron, Butorides virescens (Linn.), skin	1
Flicker, Colaptes auratus luteus Bangs, skin	1
Crow, Corvus brachyrhynchos Brehm, skin	1
Starling, Sturnus vulgaris Linn., skin	1
Redpoll, Acanthis linaria (Linn.), skins	4
American goldfinch, Astragalinus tristis (Linn.), skin	1
Pine siskin, Spinus pinus (Wilson), skin	1
Tree sparrow, Spizella monticola (Gmel.), skin	1
Chipping sparrow, Spizella passerina (Bechs.), skin	1
Slate-colored junco, Junco hyemalis (Linn.), skin	1
Myrtle warbler Dendroica coronata (Linn.), skin	1
Black-poll warbler, Dendroica striata (Forst.), skin	1
Pine warbler, Dendroica vigorsii (Aud.), skin	1
Brown creeper, Certhia familiaris americana (Bonap.), skin	1
Golden-crowned kinglet, Regulus satrapa Licht., skins	2
Olive-backed thrush, Hylocichla ustulata swainsoni (Cab.), skin	1
Hermit thrush, Hylocichla guttata palasii (Cab.), skin.	1

Fishes

Sunfish, Eupomotis gibbosus (Linn.), spec	1
Perch, Perca flavescens (Mitchill), spec	3
Roach, Abramis crysoleucas (Mitchill), spec	1

Reptiles

Ring-necked snake, Diadophis punctatus (Linn.), spec	1
Water snake, Natrix sipedon (Linn.), spec	1
Garter snake, Thamnophis sirtalis (Linn.), spec	3
Snapping turtle, Chelydra serpentina (Linn.), spec	2
Painted turtle, Chrysemys picta (Schneider), spec	1
Spotted tortoise, Clemmys guttata (Schneider), spec	2

Batrachians

Spring peeper, Hyla pickeringii (Holbrook), spec	3
Tree toad, Hyla versicolor Le Conte, spec	2
Wood frog, Rana sylvatica Le Conte, spec	3
Bullfrog, Rana catesbeiana Shaw, spec	1
Total	312

ARCHEOLOGY

Collection

Burmaster, E. R. Port Jervis site

Jesuit rings	7
Iron rings	11
Pewter ring, glass setting	1
Bronze spoon	1
String small brass beads	1
String large white beads	1
String small white beads	1
String blue glass and amber beads	1
Moorish beads	3
Shell gorgets	2
Preserved fabric, fragment	1
"R. Tippet" pipe	1
2 arm bands of copper	2
Skeletons, parts of, including skulls	30
Brass buttons	30
Hawk bells	2
Bronze bell	1
Iroquois pipes	2
Pipe bowl	1

Parker, A. C.

Gorget, broken	1
Arrowheads	30
Celt	1
Net sinkers	5
Hammer stones	2
Brass, worked fragments	4
Rude stone axes	2

Luther, D. D. Naples. From graves on Canandaigua lake

Rheolite knife	1
Stone tubes	3
Native copper chisel	1
Strings of shell beads	2
Pipe	1

Exchange

American Museum of Natural History. New York

Bannerstone, Ulster co	1
Bannerstone, Philipstown	1

Bird amulet, Sullivan co	1
Gorget (1 hole, broken) Tuthill township, Ulster co	1
Gorget (2 holes, broken) Grinnell, New Hamburg, Dutchess co	1
Grooved axe, Westchester co	1
Grooved axe, Kingston, Ulster co	1
Grooved club, Saugerties, Ulster co	1
Grooved adze, Indian Brook, Philipstown	1
Celt, New Hackensack, Dutchess co	1
Celt, Plumbush, Philipstown	1
Celt, Springtown, Ulster co	1
Gouge, Lagrange, Dutchess co	1
Pestle, Stockport, Columbia co	1
Hammerstone, Saugerties, Ulster co	2
Sherds	5
Net sinker, Esopus, Ulster co	1
Net sinker, Plumbush	1
Net sinker, Philipstown	1
Arrow points	16

ETHNOLOGY

Purchase and collection

Parker, A. C.

Delaware spoon, Grand River, Ont	1
War club, for dancing uses only	1
War club, carved with symbols of clans	1
Deer buttons, Guskaeh, set of	8
Unfinished gourd rattles, to show process	6
Brooch said to have been worn by Red Jacket	1
Modern brooches	2
Pestle	1
Mat, Chippewa	1
Eagle pole	1
Striker for pole	1
Spoon, new	1
Jerked venison on string	1
Drawings illustrating Seneca traditions	5
Beaded cap	1
Onondaga beaded cap	1
Beaded bag	1
Panther claw	1
Corn baskets	2
Corn baskets, series used for planting, harvesting and sifting	8
Carving on tree trunk	1
False face	1
Wolf mouth mask	2
Medicine masks	3
Wind blower mask	1
Bark barrel made of elm bark	1
Bark barrel, birch	1

Algonquin birch bark canoe	1
Paddles	2
Indian corn on strings, varieties	5
Indian bread	1
Paddles carved with figurines	1
Baby moccasins, pair	1
Burden strap, woven of elm bark	1
Muskrat pelt stretcher	1
Bark rattle	1
Burmaster, E. R.	
Seneca brooches	2

Purchase

Schmid, A. A. Albany	
1 string of Dutch roanoke wampum	1
Beaded bag	1
Speck, *Dr* **F. G.** Philadelphia, Pa.	
Huron toy bow	1
Huron spoons	3
Dolls	2
Beaded pockets	2
Snowshoe needle	1
Snowshoe punch	1

Donation

Alexander, C. P. Fonda	
Pottery, fragments	10
Arrow points	5
Hutchinson, *Hon.* **Frank.** Albany	
Potsherds	20
Animal bones	25
Pipe bowl	1
Lee, E. Gordon. Canandaigua	
Large adzlike celt, fine specimen	1
	327

AGE AND RELATIONS OF THE LITTLE FALLS DOLOMITE (CALCIFEROUS) OF THE MOHAWK VALLEY

BY E. O. ULRICH[1] AND H. P. CUSHING

Introduction

In a recent paper Cushing made the following statement about the Little Falls dolomite:[2]

In the correlation table on a previous page the Little Falls dolomite (the local name of the supposed Beekmantown of the Mohawk valley) is given as the equivalent of division A of the Champlain valley and of the Theresa formation of the Watertown region. It should be frankly stated at the outset that this is the element in the table whose precise position and relationship is quite uncertain. . . Ulrich's discovery of the unconformity between divisions A and B in the Champlain valley, necessitating the separation of division A from the Beekmantown formation, at once raised the question as to whether the entire Little Falls dolomite may not lie below the horizon of the unconformity and hence not be Beekmantown at all, but be properly correlated with division A and the Theresa formation and possibly even with the Potsdam. . . There is a second doubtful matter connected with the Little Falls dolomite, namely, whether or not it is a single formation. Vanuxem carefully distinguished the upper portion of the formation, the so called "fucoidal layers," from the remainder, and he has been followed in this by most other observers in the district. . . either the bulk of the Little Falls dolomite is of substantially the same age or else there is an undiscovered unconformity between it and the fucoidal layers.

During the summer of 1909 an effort was made to gain the information whose lack was indicated by the quotation above. Cushing and Ruedemann made a careful, detailed study of the section about Saratoga, following which Ulrich was shown over the section. Thereafter Ulrich and Cushing studied a series of sections, commencing at Ticonderoga in the Champlain valley, passing south to the Mohawk and thence west to Little Falls and Newport. In much of this work Ruedemann also participated.

In the following account of the results of the work, the bulk of the paper has been written by Cushing, with an occasional comment or insertion by Ulrich. The section on the "Stratigraphic position of the Potsdam, Little Falls and Tribes Hill

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[1] Mr Ulrich's contribution to this paper is published with the consent of the Director of the United States Geological Survey.

[2] Geol. Soc. Am. Bul. 19:174.

formations" was written by Ulrich, and the final chapter on oscillations is a joint production.

The section. The rocks with which this paper is especially concerned are those heretofore classed as Potsdam and Beekmantown (Calciferous). At Ticonderoga we found the ordinary Champlain succession of these rocks, Potsdam sandstone, grading up into division A of the Beekmantown through a series of passage beds, and this followed by the other four divisions of the Beekmantown, as established by Brainerd and Seely. The Potsdam is chiefly a vitreous, well cemented, light colored sandstone, with some weaker beds with calcareous cement in the upper portion. The passage beds consist of alternating beds of vitreous sandstone, calcareous sandstone, and gray dolomites which are usually somewhat sandy. With disappearance of the sandstone beds we pass into division A, chiefly a dolomite formation, largely of dark gray, finely crystalline beds below, running up into more coarsely crystalline, very light gray beds above, which are apt to be full of chert. Though not positive in the matter we are disposed to believe that Brainerd and Seely regarded the latter as forming the lower portion of their division B. At all events we find an unconformity at their summit wherever we have seen the horizon exposed, and we class them with the darker colored dolomites beneath. Frequent reefs of Cryptozoon, chiefly C. proliferum, are found in both the dark and light colored parts of the formation, and the summit is very apt to be formed of a massive, Cryptozoon reef, often heavily silicified. Lying on these in the section we measured at Ticonderoga appear beds which seem to belong to division C. The beds of dove limestone which constitute the most distinctive part of division B at Shoreham, Vt. and elsewhere in the Champlain valley are absent in the Ticonderoga section, apparently because of nondeposition. Division C is followed in order by the beds of D and E, and the last by lower Trenton, but the succession is somewhat disturbed by faulting.

Our section at Whitehall exhibited the Potsdam, passage beds and overlying dolomites, reaching up into the coarse, light colored, upper beds, but the summit and the overlying beds were not reached. What was seen was exceedingly like the corresponding part of the Ticonderoga section.

Again at Saratoga the section was quite similar, though with two prominent differences. Instead of the Potsdam grading

upward through passage beds into dolomite, the passage beds were between it and limestone, which was, in turn, followed by dolomite. This is the limestone from which Walcott obtained the Saratogan fauna which he described. It seems to us to be a calcareous phase of the lower portion of the dolomite formation. We are proposing for it the name "Hoyt" limestone and regard it as merely a local member of the dolomite. The name "Greenfield" limestone, given to it by Clarke and Schuchert, was preoccupied and must hence be replaced.

At Saratoga also there is no trace whatever of the beds of the four upper divisions of Brainerd and Seely's Beekmantown, B-E inclusive; instead the limestone heretofore called Trenton rests directly on the dolomite of division A. The Potsdam is thinner than at Whitehall and Ticonderoga, the loss being from the base.

Passing from Saratoga to the Mohawk valley the Potsdam rapidly thins out to disappearance along with the passage beds, letting the dolomite down on the Precambric. The dolomite formation, however, remains substantially as before, and is overlaid by the more calcareous formation which Vanuxem called the "fucoidal" beds. For these we propose the name "Tribes Hill" limestone, restricting the Little Falls dolomite to the beds beneath. The one overlies the other unconformably. The Tribes Hill thins westward and disappears west of Little Falls, letting the overlying Lowville limestone down on the dolomite.

The general section then, as we interpret it, is as follows:

Beekmantown	Upper divisions of the Beekmantown; unnamed as yet Tribes Hill limestone
————	Unconformity
Saratogan	Little Falls dolomite; Hoyt limestone as a local, basal phase Theresa formation; passage beds Potsdam sandstone

Historical

It is not intended here to give an exhaustive résumé of the literature which deals with the district, but merely to indicate some of the more important papers.

Vanuxem, 1842.[1] In reporting on the Calciferous group in the third district, Vanuxem distinguished three varieties of the rock:

The first silicious, compact, and perhaps a continuation of the Potsdam sandstone; the second a mixture of yellow sand and carbonate of lime, in irregular layers, the mass from whence the name *Calciferous sand rock* was derived; and third a mixture of the Calciferous material, which is usually yellowish, and of compact limestone, containing also some slaty matter. The action of the weather gives these layers the appearance of a gothic fretwork. These materials are often coated over with a greenish shale; and the whole mass has been designated, in the annual report, by the name of *Fucoidal layers.* In the annual reports the fucoidal layers were separated from the Calciferous sand rock, in consequence of always observing that they were above the great mass of the latter rock; overlooking the fact, as it seemed to be of little importance, that the fucoidal layers were always covered by a few, or more, layers of the Calciferous rock. A reattention to the subject was caused by the observations of Dr Emmons in the second district, where the mass above the fucoidal layers is greater than the one below it; the combined observations of the two districts showing that the two constitute a group, in which the fucoidal layers are included, and therefore a subordinate mass.

Fossils are rare in the Calciferous sand rock, but in the fucoidal layers there are many individuals, though the kinds are few. Most of them are peculiar to this rock. . .

As a marked difference exists between the Calciferous sand rock and the fucoidal layers, though they form one group from the intercalation of the latter, they will be treated separately, from the rule which separates objects which are different.

Comment. The above excerpts, given substantially in Vanuxem's own words, show plainly that this excellent observer was so impressed with the differences between the two formations that he described them separately, and likely would not have classed them together at all, except for the reported conditions in the second district, unfamiliar territory to him. He noted the differences in lithology and in the fossils, and also that the fucoidal layers thin out westward, being very thin at Little Falls.

Emmons, 1842.[2] Emmons, in the second district, which included the entire east and north sides of the Adirondack region, found the Calciferous in greatest variety and in greatest thickness. In the Champlain valley he included the lower Chazy in the Calciferous, and in the lower Black River region, the beds of

[1] Geol. N. Y. 3d Dist. p. 30–38.

[2] Geol. N. Y. 2d Dist. p. 105–6.

Stones River age, since separated as the Pamelia limestone. He attempted to recognize the fucoidal layers in his district, but states that they lie just above the Potsdam instead of occurring at the same horizon as along the Mohawk, and it is plain that the term, as he used it, referred to the passage beds of the Theresa formation, and not at all to the Tribes Hill limestone.[1]

Hall, 1847. In volume 1 of the *Palaeontology,* Hall describes and figures a few fossils from the Potsdam sandstone and the Calciferous sand rock. The Calciferous forms, with the exception of Lingulepis acuminata which is from the basal part, and of four species found loose, came from the upper part of the Little Falls dolomite and from the overlying, calcareous layers (Tribes Hill limestone) along the Mohawk.

Hall, 1884.[2] Describes Cryptozoon proliferum from the Calciferous of Saratoga county, with description of the genus.

Walcott, 1879–91.[3] In a series of publications Walcott refers the Potsdam sandstone to the Cambric, describes the fauna from the Hoyt limestone, and recognizes it as Cambric, though referring it at first to the Calciferous. He regards the Hoyt limestone as a local, calcareous phase of the upper part of the Potsdam sandstone and states that Lingulepis acuminata ranges up into the Calciferous sand rock, and that a species of Ophileta ranges down into the Potsdam. He draws the line between the Cambric and Lower Siluric north of the Adirondacks between the Potsdam and the Calciferous sand rock; about Saratoga in the lower part of the dolomite above the horizon of the Hoyt limestone.

Comment. Walcott's work was, of course, a great advance over everything that had preceded. We differ from his conclusions chiefly in regarding the Hoyt limestone as on the horizon of the basal portion of the Calciferous rather than of the upper part of the Potsdam; in holding that substantially the same fauna characterizes the upper Potsdam, passage beds, and lower portion of the Calciferous; and in classing the whole of the Calciferous of the Saratoga region and all of the Calciferous of the Mohawk valley, except the part here distinguished as the Tribes Hill limestone, with the Potsdam as Saratogan.

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[1] *Op. cit.* p.270.

[2] N. Y. State Mus. 36th An. Rep't Nat. Hist. pl.6, description.

[3] N. Y. State Mus. 32d An. Rep't.
Science, 3:136–37.
U. S. Geol. Sur. Bul. 30, p. 21–22.
U. S. Geol. Sur. Bul. 81, p. 205–7, 341–47, 363.

Brainerd and Seely, 1890.[1] In a most important paper Brainerd and Seeley give results of the first careful and detailed study made of the Calciferous of the Champlain valley, disclosing its great thickness and its considerable fauna. They distinguish five subdivisions of the formation which they call divisions A-E, inclusive, and map several of the most important areas in detail. The work on the whole was well done and has formed the basis for all subsequent discussion of these rocks in the Champlain valley.

Prosser and Cumings, 1896–1900.[2] In two publications are given a series of carefully measured sections with discussion, from Trenton Falls on the west through the Mohawk valley to the Saratoga region on the east. The thickness of the Little Falls dolomite in the Mohawk valley was made known for the first time and, following Vanuxem, the fucoidal layers were carefully distinguished from the dolomite beneath.

Cleland, 1900–3.[3] Announces discovery of an abundant fauna in the Mohawk valley Calciferous (fucoidal layers) which is described, and the horizon traced from Fort Hunter and Tribes Hill to Little Falls with collection of fossils at several points.

Cushing, 1908.[4] Gives a general description of the section in Jefferson county, describing the Theresa formation — a thin series of passage beds and following magnesian limestones — which directly overlies the Potsdam sandstone and is unconformably overlain by the Pamelia formation, of late Stones River age. The Theresa formation was so thin and so lithologically similar from base to summit, that it was not suspected that more than one formation was represented by it. This, however, proves to be the case, as will be later shown.

It is also argued in this paper that division A of the Beekmantown more properly belongs with the underlying passage beds and Potsdam than with the purer limestones of the remainder of the Beekmantown, and that with this readjustment the upper Cambric (Ozarkic) and the Lower Ordovicic are separated by an unconformity everywhere in northern New York.

Purpose of this paper

Our comparative study of the region has, we think, made clear the correlation of the Calciferous of the Champlain and Mohawk

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[1] Am Mus. Nat. Hist. Bul. 3:1.
[2] N. Y. State Geol. 15th An. Rep't, p.619–59.
N. Y. State Mus. Bul. 34.
[3] Am. Pal. Bul. 13, 18.
[4] Geol. Soc. Am. Bul. 19:155–76.

valleys and seems to us also to show that the Little Falls dolomite (Division A and the lower part of B) does not properly belong with the Beekmantown, either structurally or faunally, and has been heretofore classed with it simply on the basis of supposed lithologic resemblance; that it is separated from the remainder of, or rather the true Beekmantown, by an unconformity, while it invariably grades into the Potsdam beneath through a series of passage beds; and that faunally also its association is with the Potsdam, the Hoyt limestone of the Saratogan region being merely a more calcareous and more fossiliferous phase of its lower portion, of very local character, rather than a phase of the Potsdam.

Detailed sections

Commencing at Ticonderoga on Lake Champlain the sections will be given in order, passing to Whitehall, 20 miles south of Ticonderoga; to Saratoga, 35 miles farther and south-southwest from Whitehall; to Cranesville in the Mohawk valley, 20 miles southwest of Saratoga; and then west through the valley to Little Falls, Middleville and Newport, 35 to 45 miles away.

Section at Ticonderoga

Brainerd and Seely have mapped and discussed the Beekmantown section in the vicinity of Ticonderoga. It is but a few miles west of their type locality at Shoreham, and they map all five of their subdivisions of the formation. It may thus be regarded as giving a quite typical representation of the Beekmantown section of the Champlain valley.[1]

Since our purpose was a detailed comparison of a portion of the section with sections elsewhere, we made no effort to study the whole in detail. Potsdam sandstone is exposed in the creek through the village, and commencing 60 feet above the creek level we measured the following section up the hill to the north, known as Mount Hope, the 60 foot gap probably consisting partly of Potsdam and partly of passage beds:

SECTION JUST NORTH OF TICONDEROGA

	Feet	Inches
34 Light gray, finely crystalline limestone, to top of exposure	1	8
33 Gray, calcareous sandstone	7	

[1] Am. Mus. Nat. Hist. Bul. 3:10–14.

	Feet	Inches
32 Blue gray dolomite; cross-bedded, rather coarse grained; frequent drusy cavities with calcite and quartz; very sandy midway with chert pebbles and flat, fine grained pebbles	3	6
31 Medium grained, gray, crystalline limestone; many nodules of crystalline calcite centrally	11	
30 Hard, vitreous sandstone, irregular at base over the nodular surface of the limestone beneath	1	
29 Gray, crystalline limestone, in four beds, finer grained toward top	4	
28 Gray white sandstone, somewhat calcareous	1	10
27 Hard, vitreous, whitish sandstone, coarsely ripple-marked above	2	
26 Gray crystalline limestone, with calcite nodules	1	3
25 Alternations of thin, slaty limestone and thin seams of gray, magnesian limestone, much laminated	12	
24 Upper half of gray dolomite, lower of dark gray, oolitic limestone	1	7
23 Earthy, magnesian, rotten limestone, surface nodular and of red color		7
22 Dark gray, oolitic, magnesian limestone, ovules weathering blackish	4	6
21 Fine grained blue limestone, weathering drab; earthy and somewhat laminar; upper 2 inches shaly and with nodular surface which weathers red	5	4
20 Similar to that above; very uneven upper surface with 1 inch to 3 inches red, laminar shale as cover, 3 feet, 6 inches to	4	
19 Dark gray, oolitic, magnesian limestone, ovules weathering blackish		8
18 Blue, earthy, fine grained, somewhat laminar limestone; weathers drab	2	4
17 Dark blue gray, crystalline, suboolitic limestone; upper surface is irregular and weathers red	1	2
16 Thin, sandy, blue limestone bands with shale partings, and one 4 inch seam of cross-bedded sandstone; upper 1 foot very thin bedded, and reddish; holds *Lingulepis acuminata*	3	6
15 Thin, irregular, shaly limestone, with fucoidal markings and *Lingulepis acuminata*		4

		Feet	Inches
14	Hard, whitish, vitreous sandstone................		10
13	Dark blue gray limestone, finely crystalline, heavy bedded, frequent grains of fine quartz sand.....	7	
12	Hard, white, vitreous sandstone.................	2	3
11	Dark gray blue, calcareous sandstone, weathering to brown, rotten stone, especially above........	4	4
10	Gray, finely crystalline, somewhat magnesian limestone, with occasional sand grains; thick bedded; upper surface ripple-marked....................	9	3
9	Irregular parting of shaly limestone with fucoidal markings		2
8	Gray, subcrystalline limestone, with sparing quartz grains; lower portion laminated and mottled with black films............................	2	
7	Dark to light gray, subcrystalline, magnesian limestone; thick bedded; many rounded sand grains; calcite nodules in upper portion..............	7	
6	Gray, magnesian limestone like that below.......	1	8
5	Concealed	1	8
4	Gray limestone like that beneath but lighter in color	1	
3	Fine grained, finely crystalline, gray, magnesian limestone, with fine, interrupted black lines; fucoidal markings; sand grains abundant on upper surface, otherwise sparse....................	2	
2	Shelly, laminar, calcareous sandstone, with streaks of pure sandstone; fucoidal markings..........	3	
1	Blue, crystalline limestone with occasional small, rounded sand grains.........................	1	3
	Total thickness	112	8

This section is on the general horizon of the Hoyt limestone of the Saratoga section, though including somewhat more than that, both at top and bottom. It is also the same as the lower portion of the Whitehall section and shows the beds which are concealed there. A somewhat unusual feature of it is the distance upward through which sandstone layers of Potsdam characters run. According to Brainerd and Seely's map they regarded the lower part of this section as belonging to division A and the upper to B.

One mile to the east of this section is another which shows higher beds, an additional thickness of about 100 feet being exhibited. The section is exceedingly similar to that of the upper portion of the Little Falls dolomite at Saratoga, bluish gray, finely crystalline dolomite below, often with bad odor when freshly broken, with many nodules of crystalline calcite, often drusy, and with coarser grained, whitish, crystalline dolomite above, with much black chert; the section capped by a massive 6 foot reef of Cryptozoon, much of which is chert. This is directly and unconformably overlaid by beds which seem to us to belong to division C; certainly they have the lithologic character of that division. These are followed in their turn, going north, by the beds of divisions D and E.

Discussion. The bulk of this second section is mapped by Brainerd and Seely as belonging to division B. They describe the division as follows:

Dove-colored limestone, intermingled with light gray dolomite, in massive beds; sometimes for a thickness of 12 to 15 feet no planes of stratification are discernible. In the lower beds, and in those just above the middle, the dolomite predominates; the middle and upper beds are nearly pure limestone.[1]

We found no dove limestone in the section. Likely the light gray dolomite is that forming the upper part of our section, though if it be, we fail to understand the lack of mention of the chert which we find in it everywhere abundantly. In any case it is the same horizon which we find everywhere to characterize the summit of the Little Falls dolomite. In this section it is, as we believe, in uncomformable contact with division C and this is followed by the whole of D and E, the two upper members of the Champlain Beekmantown. Except where eroded away during the time interval which followed, the summit of the Little Falls dolomite at Ticonderoga and elsewhere is usually a Cryptozoon reef, often heavily charged with chert, as is the case here.

Section at Saratoga

The Saratoga district is considerably faulted; glacial drift is widespread and often heavy, and a complete, detailed section can not be made out from study of the surface outcrops. The Mohawkian rocks rest on an uneven, eroded surface of the dolomite group, varying beds of each group being at the contact in the different exposures. The general section is as follows:

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[1] *Op. cit.* p. 2.

Trenton limestone; with usually a small thickness of Black River limestone beneath

Unconformity

Little Falls dolomite; light gray to dark gray, crystalline to subcrystalline dolomite, sharply bounded rhombs embedded in a cement which is more or less calcareous and dissolves away leaving surfaces of sandy appearance; certain layers are full of nodules of crystalline calcite, others are drusy and hold calcite and quartz crystals; black and gray cherts are frequent at certain horizons; a Cryptozoon reef occurs in the upper part of the formation in a dove limestone band; otherwise fossils are very scarce. Thickness at least 150 feet and possibly 200 feet

Hoyt limestone member; blackish, subcrystalline, pure or only slightly magnesian limestone alternating with beds of blue and light gray dolomite; quartz sand grains in some of the beds, increasing in amount below; in the lower portion beds of calcareous sandstone and more rarely of quartzose sandstone; contains many beds of black oolite, most abundant near the base; contains Cryptozoon, trilobites, gastropods, and Lingulepis acuminata at many horizons. Thickness 80-120 feet

Passage beds from the Hoyt limestone to the Potsdam sandstone; alternating beds of hard, vitreous sandstone, gray, calcareous sandstone, blue or gray, crystalline dolomites and magnesian limestones, and black, oolitic beds; contain trilobites and Lingulepis acuminata. Thickness 40-60 feet

Potsdam sandstone; light colored, vitreous sandstone, with occasional layers of calcareous sandstone in the upper portion, and more or less coarsely conglomeratic beds at base; thickness variable because of overlap on an irregular erosion surface of Precambric rock; from 60 feet to more than 200 feet

So far then as can be told from the surface exposures the thickness of the beds between the Potsdam and the Mohawkian is from 300 to 350 feet.

The most complete and continuous section of the upper beds of the Little Falls dolomite seen is that along the roadside east of Highland Park. Here the following section was measured.

SECTION EAST OF HIGHLAND PARK

		Feet
14	Gray, subcrystalline dolomite, with a small amount of calcite cement; great masses of gray to black chert at summit, and in smaller amount at lower horizons; frequent irregular spots and films of coarsely crystalline calcite, to top of exposure	7
13	Medium coarsely crystalline, light gray dolomite, containing locally much gray and black chert; somewhat brecciated along ancient dislocation surfaces, the interspaces now filled by blackish, subcrystalline calcite	9
12	Laminated layer of light and dark gray, subcrystalline dolomite, with small nodules of crystalline calcite	1
11	Gray white, subcrystalline, hard dolomite, with frequent drusy cavities lined with dolomite, calcite and quartz crystals, quite like those in the Little Falls region, the dolomite crystals having formed first and the quartz last	5

The above section is shown in the Maple ave. quarry near the fault line, at the north edge of Saratoga Springs; from the quarry the basal layer can be directly traced around to the north along the hillside to where it comes out on Broadway and forms the upper bed of the section shown down the hill toward St Clements.

		Feet
10	Medium coarsely crystalline, gray to gray white dolomite, somewhat mottled in appearance, with some calcite cement between the dolomite rhombs; very full of chert	12
9	Very massive, gray, granular to subcrystalline dolomite, full of large and small nodules of crystalline calcite	10
8	Unexposed	12
7	Massive layer of gray, granular dolomite with calcite spots, quite like that above gap	5
6	Dark gray, hard, finely crystalline dolomite, bad smelling when freshly broken; occasional small cherts, and spots of crystalline calcite; very massive and irregularly bedded	10
5	Somewhat lighter colored than that above, less odor and with no chert, otherwise similar	10

		Feet
4	More of the dark gray, evil smelling dolomite, like that above; all is somewhat porous, the voids between the dolomite rhombs not thoroughly cemented up; there is always a small percentage of calcite cement..........	11
3	Concealed	11
2	Gray, finely crystalline dolomite, lighter colored than that above and below, very massive, marked with dark colored lines, and containing some chert................	15
1	Dark, blue gray, porous dolomite, at base of section.....	1
		119

This section terminates at the north in the angle between two branches of a fault, making it impossible to determine what thickness of similar beds may lie beneath. The light gray, crystalline dolomites of the upper portion of the section continue on to the south through Saratoga, with likely some additional beds which do not appear in the section, but the thickness of such can not be great — probably less than 15 feet. Four miles west of Saratoga a hill composed of these same beds is capped by a dove limestone layer which is a great Cryptozoon reef. and which is likely at a somewhat higher horizon than any bed of the section; but it lies upon light gray, crystalline dolomites precisely like those which form the upper beds of the Highland Park section and can not be greatly higher than these.

The best section of the lower beds, Potsdam sandstone and Hoyt limestone, is found along the Adirondack Railroad to the west of Saratoga. It is as follows, the beds being numbered from below upward:

CONSECUTIVE SERIES OF SECTIONS EXPOSED IN CUTS ALONG THE ADIRONDACK RAILROAD AND NEARBY QUARRIES BETWEEN GREENFIELD STATION AND SARATOGA

40 Exposures at Hoyt quarry; hard, blue to blue black, subcrystalline to crystalline magnesian limestones, largely of dolomite rhombs with calcareous cement; 1 foot from the top is a Cryptozoon reef, and the base is composed of another, the one shown by the roadside near the farmhouse, from which Hall originally described Cryptozoon proliferum; the rock is partly thin, and partly thick bedded; some of the layers

	Feet
show coarsely crystalline calcite cement, giving large, glittering cleavage faces on freshly broken surfaces; trilobites, Lingulepis and gastropods are found from bottom to top	25

One third mile north of the Hoyt quarry is another quarry face by the roadside, capped by the same Cryptozoon layer which forms the base of the Hoyt quarry section.

	Feet	Inches
39 Dark blue, subcrystalline, magnesian limestone, full of Cryptozoon; frequent, black oolitic grains.	1	5
38 Massive beds of blue, finely crystalline magnesian limestone, with occasional sand grains; trilobite fragments	5	5
37 Thin bed of calcareous sandstone, weathering to brown, rotten stone		5
36 Two beds of dark blue, crystalline, magnesian limestone with occasional sand grains	2	5
35 Layer of dark gray, calcareous sandstone	1	7
34 Layer of light colored, vitreous sandstone, with films of darker material with calcareous cement	1	3
33 Dark colored sandstone with calcareous cement		4
	12	10

Four tenths of a mile northeast of this are two considerable cuts along the Adirondack Railroad in which the following section is shown. The hiatus between the two is estimated at 20 feet.

	Feet	Inches
32 Dark blue, subcrystalline magnesian limestone	1	3
31 Blackish oolitic dolomite	1	8
30 Dark blue, crystalline dolomite, with calcite cement, showing large, lustrous cleavage faces; holds Lingulepis acuminata		10
29 Black, oolitic dolomite, containing pebbles of mud limestone	1	8
28 Rotten, crystalline dolomite, calcite cement rapidly leaching out		5
27 Blackish, oolitic dolomite in three beds, the upper a Cryptozoon bed; frequent sand grains and many drusy cavities containing quartz and calcite crystals	2	6

		Feet	Inches
26	Easily rotting, crystalline dolomite, calcite cement, very shaly above		9
25	Hard, light colored, vitreous sandstone	1	4
24	Crystalline, bluish dolomite, poorly cemented by calcite	1	7
23	Two massive beds of blackish, subcrystalline, magnesian limestone, with frequent sand grains, to base of westerly cut	4	3
22	Concealed between the two cuts; boundary between Hoyt limestone and the passage beds to the Potsdam, about	20	
21	Rotten, brown, calcareous sandstone, blue when fresh		8
20	Hard, vitreous, light colored sandstone, banded with narrow streaks of darker colored sandstone with calcareous cement	2	4
19	Thin bedded, blue, calcareous sandstone, weathering brownish		9
18	Blue black, oolitic dolomite, frequent rounded quartz grains, many small drusy cavities	1	3
17	Blue, calcareous sandstone, weathering light colored, upper portion shaly	1	8
16	Hard, light colored, vitreous sandstone	1	6
15	Thin bedded, calcareous sandstone, somewhat oolitic, blue when fresh but rapidly weathering brown-mottled and crumbly, many drusy cavities, with calcite and quartz crystals; abundant trilobite fragments, constituting the lowest zone of these so far discovered near Saratoga	1	3
14	Light colored, vitreous sandstone	2	5
13	Bluish, nodular, finely crystalline dolomite, with a slight amount of calcite cement, shaly at top and bottom, with frequent nodules of crystalline calcite; holds Lingulepis acuminata	2	3
12	Light colored, vitreous sandstone	1	3
11	Gray, banded sandstone, slightly calcareous	3	9
10	Alternating calcareous sandstone and crystalline dolomite, of blue gray color, large nodules of crystalline calcite in the latter; base of cut	3	
9	Concealed between this and the next cut to the east, about	30	

	Feet	Inches
8 Hard, vitreous, light colored sandstone, with darker calcareous sandstone above and below..	1	8
7 Concealed to brook exposures next east; arbitrary boundary between passage beds and Potsdam in the interval, about..........................	30	
6 Light colored, vitreous sandstone, with alternating layers of darker, calcareous sandstone which weather rapidly............................	30	
5 Light colored, vitreous sandstone...............	15	
4 Concealed	4	
3 Light colored, vitreous sandstone...............	2	
2 Concealed	4	
1 Conglomerate, increasing in coarseness downward, and reaching nearly to the base of the formation.	10	

In this section we find then a thickness of 94 feet, 1 inch of the Hoyt limestone member of the Little Falls formation, counting in with it the 20 foot gap between it and the passage beds, with the summit of the member not reached; beneath it a thickness of 52 feet, 1 inch of what we class as passage beds, counting in with them the 30 foot gap between them and the Potsdam; and finally 96 feet, 8 inches of Potsdam with the base not reached, though it is unlikely that as much as 10 feet lies beneath. We find essentially the same trilobite fauna ranging through a thickness of at least 100 feet, commencing in the passage beds and continuing up through the entire thickness of the Hoyt limestone. There is a measured thickness of 119 feet of Little Falls dolomite above the Hoyt member in the Highland Park section which shows neither the base nor the summit. We are, however, disposed to think that the entire thickness of this part of the formation is not greatly in excess of this, and that the coarsely crystalline, light colored dolomite of the upper part of the Highland Park section constitutes the summit of the formation about Saratoga. In the northern part of the village just south of the quarry which furnished the top of our measured section and close to the fault are a few thin patches of Mohawkian limestone, resting upon these upper beds and apparently directly deposited upon them. The Mohawkian is a conglomerate with many pebbles of the underlying dolomite. The horizon of this contact is certainly not more than 20 feet above the top of the quarry section.

The thickness of the beds that may lie beneath the bottom of the Highland Park section and the top of the Hoyt limestone member in the Hoyt quarry, in other words the thickness of the beds belonging between the base of the former section and the top of the latter, is much less certain, but so far as can be judged from sections elsewhere the amount is not great. Estimating the Hoyt at a maximum of 100 feet and the upper member at about 150 feet, the total thickness of the Little Falls formation in the vicinity of Saratoga may be set down as approximately 250 feet. The maximum may fall a trifle under this figure, but it is quite certain that it does not exceed 300 feet. Locally, however, on account of Premohawkian erosion the thickness may be considerably less.

At Rock City Falls, 7 miles west of Saratoga, contact with the Mohawkian is well exposed. Here this Ordovicic limestone rests upon darker colored dolomites of the Little Falls formation which seem to belong beneath the coarse, whitish rocks of the upper portion. Midway between Saratoga and Rock City Falls are other exposures which show Mohawkian limestone resting on similar beds, though the higher, coarse grained, whitish beds are near at hand, and in such situation that we can only interpret the exposures as indicating that the Mohawkian was deposited on an eroded surface of the Little Falls dolomite, beds being absent in some sections both above and beneath the unconformable line of contact that are present in others. The evidence seems clear to us that the whitish summit beds of the Little Falls have been eroded away locally, the Mohawkian in such cases resting on lower beds.

The lower part of the Mohawkian varies greatly within and in areas adjacent to the Saratoga quadrangle. As a rule the basal Mohawkian beds in this region have been assigned to the Trenton, but, so far as observed, they are in all cases older than the lowest Trenton in the type sections on West Canada creek. At the same time, however, the first Ordovicic bed to follow the Little Falls dolomite, or the Tribes Hill formation and the thin irregular wedge of Lowville where these are present, is younger than the Watertown limestone ("7 foot tier") of the Black River group. In other words, in the area between Saratoga on the east and say Canajoharie on the west, the post-Lowville Mohawkian begins with beds that are wanting along West Canada creek and Black river. At Saratoga a 6–10 foot, heavy bedded crystalline limestone is found either resting on or not more than 5 feet above the top of the Little Falls dolomite. At Rock City Falls, 6 miles west, this bed

lies about 30 feet above the dolomite, the basal layers of the underlying interval being unquestionably of the Black River group but not so low as the Lowville and probably also younger than the Watertown limestone. The Lowville is represented by 2–4 feet of beds at Tribes Hill in the Mohawk valley, but here the crystalline limestone is only 3 to 5 feet above it. The section at this locality differs further in that it contains an unusual thickness (13 to 18 feet instead of 2 to 10 feet) of somewhat shaly limestone above the crystalline bed before the Prasopora simulatrix fauna, with which the typical Trenton begins in New York, sets in. This irregularly distributed, presumably late Black River formation, intervening between the true Trenton above and the more typical Black River formations (Lowville and Watertown) beneath, will be fully described in another paper. Here it will suffice to say that it wedges out westwardly in the Mohawk valley before reaching Little Falls. So far as known its maximum aggregate thickness is about 60 feet, the lower 46 feet of which is exposed at Rock City Falls. A good thickness is shown also in the section at Glens Falls.

The work of Prof. W. J. Miller on the Broadalbin quadrangle (next west of the Saratoga quadrangle) in 1909 shows that there the Hoyt limestone is absent from the section, being replaced by unfossiliferous dolomites and probably also by beds included in an increased thickness of passage beds between the dolomite and the Potsdam.

The well drilled at the Hathorn spring in Saratoga a few years ago is reported to have begun in the Trenton limestone and to have passed through some 700 feet of limestone before reaching the Potsdam. This is a thickness at least 300 feet greater than the surface exposures indicate. The well is near a fault and it seems probable that it crosses a branch of the fault in such wise as to repeat a considerable thickness of the limestone.

Section at Whitehall

Whitehall is between Saratoga and Ticonderoga and thus, from the standpoint of distance, serves as a convenient intermediate point between the two. The district is much faulted, but a good, continuous section is afforded from the Precambric up through the Potsdam and well toward the summit of the Little Falls dolomite, simply by ascending the hill known as Skene mountain, a fault block whose summit rises sharply to more than 400 feet above the level of Wood creek. Walcott has given a detailed section of the Pots-

dam and passage beds at this point and a more generalized section of the dolomites above.[1] We were more concerned with the upper part of the section than with the Potsdam and made the following measurements down the south face of the hill, where the section seemed most complete:

SECTION OF LITTLE FALLS DOLOMITE AT SKENE MOUNTAIN NEAR WHITEHALL, N. Y.

		Feet
7	Whitish, rather coarsely crystalline dolomite, with a little chert at summit; this material forms the summit of the knob everywhere and is of greater thickness than 10 feet, that being only what is shown where the section was measured	10
6	Mostly very finely crystalline, dark gray magnesian limestone somewhat cherty above; full of irregular seams of more coarsely crystalline material which weathers less readily and forms projecting films on weathered surfaces; lower portion very massive forming high cliff; at base a single trilobite fragment was found	90
5	Very coarsely crystalline, whitish dolomite, somewhat oolitic and becoming steadily finer grained downward	30
4	Gray blue, finely crystalline dolomite with calcareous cement, weathering sandy looking, many calcite-filled cavities; at base a Cryptozoon horizon	50
3	Blackish, oolitic, magnesian limestone	20
2	Measures concealed	50
1	Passage beds: chiefly calcareous sandstone, but with alternating beds of vitreous sandstone and blackish, crystalline, sandy limestone; only a 15 foot thickness of these shows on the south face but, followed around to the west side the full thickness comes in with the large thickness of Potsdam underneath which Walcott measured, the dip being strong to the east	80
		330

This section is much like those at Saratoga and Ticonderoga. The horizon of the Hoyt limestone is largely concealed, but the black, oolitic beds above the gap are exceedingly like those as-

[1] U. S. Geol. Sur. Bul. 81, p. 345.

sociated with the Hoyt. Beds 17 to 24 of the Ticonderoga section are thought to represent the same horizon. Walcott reports Lingulepsis acuminata in the passage beds. All the upper portion of the section has the typical characters of the middle and upper parts of the Little Falls dolomite, but unfortunately the summit is not quite reached. Loose chert, apparently from the upper part of the dolomite, found 2 miles northeast of Whitehall, contains two gastropods and a cephalopod that mark the middle part of the Ozarkic in Missouri. The same beds there contain trilobites closely allied to those found in the Hoyt limestone near Saratoga.

In the National Museum is a small collection of fossils made by Walcott from 2 miles north-northeast of Whitehall which contains a half dozen specimens of the fauna of division D and demonstrates the presence of at least that member of the Beekmantown. Since Whitehall is due south of Ticonderoga and much nearer that point than Saratoga, it is quite likely that other members of the Beekmantown were deposited in this region.

Mohawk valley sections

Passing southward from Saratoga to the valley exposures the Potsdam sandstone rapidly thins and disappears, letting the passage beds and then the Little Falls dolomite down on the Precambric. The manner of disappearance seems to us to indicate plainly that the Potsdam vanishes because of overlap, and that the dolomite of the valley is the direct equivalent of that of the Saratoga and Ticonderoga sections and wholly above the Potsdam. The paleontological evidence, so far as it goes, confirms this belief.

In the most easterly of the Mohawk valley sections a limestone formation of considerable thickness, the "fucoidal layers" of Vanuxem, overlies the dolomite. This limestone is thickest at the east and thins westward to complete disappearance west of Little Falls. The published sections of Prosser and of Cleland, with the faunal studies of the latter, left no doubt of the fact of the general persistence and equivalence of both the dolomite and limestone formations throughout the valley, hence our comparative study seemed to call for sections only at the east and west ends respectively. We measured and studied sections at Tribes Hill and Cranesville at the east, and at Little Falls, Middleville and Newport at the west.

SECTION AT CRANESVILLE

	Feet	Inches
19 Irregular, thin bedded, crystalline limestone, with Solenopora compacta and other fossils; 9 inches to	2	1
18 Thin bedded, fine grained, somewhat argillaceous limestone often nodular; contains Tetradium; 4 feet to	5	
17 More coarsely crystalline, otherwise like that just beneath	2	
16 Massive, blue gray, subcrystalline limestone, often lumpy, with abundant, subangular limestone pebbles from the dolomite below; many fossils, Columnaria, Tetradium etc.; 6 to	10	
15 Dove limestone of Lowville character, often not appearing; base of Lowville; 0 to	1	
Unconformity	....	....
14 Thin bedded, earthy, gray dolomite, weathering shaly	18	
13 Unexposed	5	
12 Sandy, laminar, gray dolomite, containing Ophileta disjuncta	1	
11 Concealed	40	
10 Hard, blue gray, fine grained dolomite	2	
9 Unexposed	20	
8 Laminar, fine grained dove limestone, mottled with strings and patches of argillaceous dolomite, suggesting fucoids; contains Eccyliomphalus	25	
7 Unexposed	45	
6 Thin bedded, alternating limestone and shaly limestone, with pure limestone at base; many fossils, chiefly gastropods; base of Tribes Hill	12	
Unconformity	....	....
5 Whitish, rather coarsely crystalline dolomite on hillside between the forks of the road	15	
4 Unexposed	10	
3 Thin bedded, argillaceous, gray dolomite, very irregular above and with rolls in the lower portion	18	

	Feet	Inches
2 Light to dark gray, crystalline dolomite, many nodules of crystalline calcite, often large; many of the beds have calcareous cement and weather porous, crumbly and sandy looking............	20	
1 Concealed to level of Mohawk..................	90	

Though this section is very imperfect, yet it gives both the upper and lower contacts of the Tribes Hill limestone with a thickness of 168 feet for the formation in this section. The base is well shown and is distinctly unconformable on the dolomite beneath. The Little Falls dolomite has the general characters that it shows in all sections, the coarsely crystalline, whitish beds above, and darker, finer grained beds below. The base of the dolomite is below the river level, but it is quite certain that the Potsdam is still in place beneath. The Amsterdam sheet, midway of which this section occurs, corners on the Saratoga sheet at the southwest and is distant only 20 miles from the Saratoga section. On the Broadalbin sheet (north of Amsterdam and west of Saratoga) Miller finds the Potsdam running all the way across the sheet from east to west. The section differs from that at Saratoga chiefly in that the Tribes Hill formation has come in between the Little Falls and the overlying Mohawkian. It differs from the Ticonderoga section in that none of the Beekmantown except the Tribes Hill division appears. The section was measured up the creek which comes into the Mohawk at Cranesville from the north, diverging from the creek up the left-hand road, 1 mile north of the river. Cumings had previously published the same section though we subdivide somewhat differently and find the thickness of the upper part less than he gives it.[1]

Section at Tribes Hill

At Tribes Hill, 8 miles west of Cranesville, we also measured the section. The locality is just across the river from Fort Hunter, where the original discovery of the fauna which Cleland described was made.[2] The section at Tribes Hill is much less complete than at Cranesville, but we have chosen it as the type locality because of the excellent exposure of the characteristic fossiliferous limestone of the formation which is found

[1] N. Y. State Mus. Bul. 34, p. 441.

[2] Am. Pal. Bul. v. 3, no. 13.

along the creek which flows southeast through the village. This section was carefully measured by Cleland and as here given is practically a reproduction of his, a few lithologic data being added.[1]

SECTION IN CREEK NORTH OF METHODIST CHURCH, TRIBES HILL

	Feet	Inches
7 Layer of compact, dove limestone, probably Lowville		4
Unconformity	....	....
6 Rather dark gray, hard, fine grained, somewhat laminar dolomite, breaking with conchoidal fracture	12	8
5 Alternating dove limestone and sandy, laminated, magnesian limestone, in undulating, irregular layers; main horizon of Dalmanella wemplei	7	7
4 Argillaceous, yellowish dolomite, or magnesian limestone, capped by a 1 inch layer of limestone conglomerate with fossils	4	
3 Finely granular, blue limestone, which is conglomeratic and oolitic, and exceedingly fossiliferous; abundant Ribeiria and small gastropods	2	6
2 Massive, slightly argillaceous, gray, magnesian limestone, with occasional fossils	7	5
1 Blue gray limestone which is somewhat conglomeratic and contains fossils in considerable number	3	1

This section furnishes a thickness of 37 feet, 3 inches of these typical fossiliferous beds. The base of the section is nearly 200 feet above the river level, but the underlying beds are exposed in very fragmentary fashion. The dip is strong to the west and brings this horizon down to the level of the railroad at the Tribes Hill depot. A short distance east of the depot is a considerable quarry in these beds which was carefully measured by Prosser.[2] There are also quarries just west of the depot where the Lowville and overlying limestones are well shown, with the summit of the Tribes Hill limestone beneath. In both these sections there is a thickness of from 15 feet to 20 feet of gray, magnesian limestone and dolomite at the summit of

[1] Am. Pal. Bul. v. 4, no. 18, p. 6–8.
[2] N. Y. State Geol. 15th An. Rep't, p. 645.

the Tribes Hill which certainly differ from bed 6 at the top of the formation in the section in the village just given. As the Lowville and other Black River limestones are thicker in the quarry at the depot than in the village section it is thought likely that, in part, the westward dip may signify descent of the beds into an original synclinal basin in which the Tribes Hill formation retained beds that were eroded in nearby areas.

Western sections

It was our intention to study the section at Sprakers about midway of the valley, where the Precambric is brought up on the west side of the fault, and the full thickness of the "Calciferous" is shown. We were, however, unable to do so and hence can not state whether the contact between the Little Falls dolomite and Tribes Hill limestone is here exposed or not. However, considering that wherever observed the formations maintain unconformable relations to each other there seems no reason to doubt that similar conditions will be found to obtain also at Sprakers. Prosser has given two carefully measured sections at this point, one of the cliff at the West Shore Railroad cut, the other along Flat creek.[1] The Potsdam is absent, having disappeared through overlap. The first section shows a thickness of 490 feet, the lower 385 feet of which belong apparently to the Little Falls, the upper 40 feet belong certainly to the Tribes Hill, while between the two is an interval of 65 feet with infrequent exposures which in all probability belongs mostly or entirely with the Tribes Hill. The summit of the formation is not reached. Prosser reports Cryptozoon about 200 feet above the base in the Little Falls, and the Tribes Hill fauna in the upper 40 feet of the section. The Flat creek section, capped by Mohawkian limestone, shows 190 feet of rock, the upper 95 feet of which Prosser assigns to the Tribes Hill (fucoidal beds) and the lower portion to the Little Falls. Except for lack of knowledge in regard to evidence of unconformity between the two formations and the precise horizon of the break, the section is perfectly clear.

Section at Little Falls

The best section at Little Falls is that along the creek to the northwest of the town, where the upper beds and all the contracts

[1] N. Y. State Geol. 15th An. Rep't, p. 641–43.

are fully shown. The contact of the Little Falls dolomite on the Precambric is also shown, but a complete section of the dolomite is nowhere to be found on the north side of the river. The creek section follows, commencing at the base of the Trenton.

SECTION IN SMALL CREEK AT NORTHWEST EDGE OF LITTLE FALLS

	Feet	Inches
Base of *Prasopora simulatrix* bed of Trenton		
Hiatus	....	....
20 Brittle dove limestone; normal Lowville	7	11
19 Basal, less typical Lowville beds; dove limestone with many rounded quartz grains, in increasing amount downward	3	11
18 Shaly layers of varying thickness; base of Lowville; 0 to		3
Hiatus	....	....
17 Thin bedded and somewhat shaly layers of dove limestone and dove limestone conglomerate, the pebbles of which are embedded in crystalline limestone; considerable pyrite; found two trilobite fragments.	1	6
16 Thin bedded, hard, brittle, blue dove limestone with shaly partings; full of stems and plates of cystids and with fewer gastropods (*Ophileta levata*) and trilobite fragments in very bad preservation	3	6
15 Two massive beds of bluish, finely granular limestone, somewhat mottled with crystalline seams; rude fucoidal markings on surface; contains *Pleurotomaria hunterensis*	4	8
14 Similar to above, somewhat less like dove limestone, fine wormlike tracks on surface, upper bed weathering finely but unevenly laminar	2	8
13 Massive, 1 foot to 2 foot beds of dark, blackish gray, firm, hard, fine to medium crystalline dolomite, mottled with black streaks	7	7
12 Finely granular, gray dolomite, some beds having calcareous cement and weathering reddish and sandy looking; it is unconformable with the irregular surfaced layer beneath, whose surface the stream follows for some yards, the slope being greater than the dip of the beds above, so that an additional 6 foot thickness comes in; where thickest the basal		

		Feet	Inches
	layer is a conglomerate, with large but thin black pebbles in a reddish, calcareous matrix; in the lower portion of the bed the pebbles lie flat, but above they are disturbed and may stand on edge; base of Tribes Hill; 24 feet to	30	
11	Hard, finely granular, gray dolomite, with coarsely lumpy surface; 0 to	6	
10	Hard, finely granular, massive, gray dolomite, with some calcareous cement, and weathering reddish; a strong chert bed at the summit	24	
9	A ponderous Cryptozoon reef of varying thickness, heavily silicified forming variegated black and gray chert; its upper irregular surface is thinly covered with gray, crystalline dolomite; beneath is a varying thickness of from 4 to 7 feet of finely crystalline, dark gray dolomite	10	
8	Porous, blocky, gray dolomite, dolomite crystals in calcareous cement, weathering whitish; many sand grains	10	
7	Gray, finely crystalline, porous dolomite, calcareous cement; drusy cavities with dolomite, calcite and quartz crystals; frequent quartz grains on the upper and lower surfaces of the beds; holds thin, twisted chert plates which suggest Cryptozoon	25	
6	Finely crystalline, gray dolomite	35	
5	Medium coarse grained gray dolomite, weathering sandy looking because of calcareous cement; a Cryptozoon reef at base	30	
4	Concealed	20	
3	Medium coarsely crystalline, gray dolomite with calcareous cement; thin chert seams of Cryptozoon character in the upper portion	15	
2	Concealed	30	
1	Light gray, rather coarsely crystalline dolomite, with some rounded grains of quartz sand, in 6 to 18 inch layers; cement in part calcareous; a thin streak of very black, shaly material near base; frequent, blackish, drusy cavities	30	

This section does not reach the base of the formation, but the lower beds are well shown in the eastern portion of the town with

an additional thickness of some 150 feet. Almost at the base is the shaly zone with Lingulepis acuminata, first reported by Shaler and H. S. Williams.

Though the outcrops are not entirely satisfactory, there is reason to believe that the unconformity at the base of the Tribes Hill limestone locally descends in this vicinity to the top of the ponderous Cryptozoon chert included in bed 9 of the above section. This condition is suggested on the ridge just west of the creek. That the floor on which the Tribes Hill was laid down was uneven is shown by comparison of the two detailed sections made on the north side of the river in the bluffs back of Little Falls. In the section exposed in the creek on the northwest edge of the town, as above described, the Tribes Hill has a thickness of about 50 feet. The silicified Cryptozoon reef of the Little Falls dolomite, which seems to be a persistently marked zone in this vicinity, lies here about 30 feet lower, hence 80 feet beneath the base of the Lowville. Less than 200 feet to the west the 30 foot interval is reduced to about 18 feet. The basal bed of the Tribes Hill (no. 12 of section) also is reduced from 30 feet to about 16 feet. In a branch of this creek about 1/6 mile east, the Cryptozoon bed is only 58 feet beneath the Lowville and only 21 feet beneath the base of the Tribes Hill, which, therefore, is but 37 feet thick at this point. The loss of 13 feet, when compared with the section in the main branch of the creek, is found to be divided between the top and bottom, beds 16 and 17 of that section, aggregating 5 feet, being absent here. The other 8 feet probably are lost from the base, though the character of the middle and lower beds of the Tribes Hill varies rapidly from place to place so that the individual beds are not easily recognizable. A mile farther east, along the road to the quarries northeast of Little Falls, the Tribes Hill seems even thinner, but the exposures are too poor and the dip not sufficiently regular to permit a definite statement on this point.

In mapping the Little Falls sheet it was shown that the dolomite formation rapidly thinned because of overlap, in passing across the quadrangle from south to north. It was at that time supposed to be a single formation, and the loss by overlap was supposed to be at the base. Since, however, we are dealing with two, unconformable formations it may well be that both thin northward because of overlap, and that the Tribes Hill disappears before the Little Falls does, letting the Lowville down upon the latter. Until the quadrangle is restudied it is impossible to definitely pronounce

upon the matter. A study of the section at Middleville, 9 miles northwest of Little Falls, seems, however, to indicate that both formations thin to the north owing to overlap, and that the Tribes Hill pinches out long before the Little Falls does. In the Middleville section the Tribes Hill has apparently disappeared; certainly the fossiliferous, dove limestone beds do not occur. Since the formation still has a thickness of 50 feet at Little Falls and has not been thinning westward from Cranesville at a rate exceeding 2 feet per mile, it is not impossible that this sudden disappearance is attributable to the distance north, rather than the distance west from Little Falls. However, in mentioning the average westerly reduction of the formation it is not to be understood that we regard this as taking place gradually. On the contrary, as intimated in the preceding paragraph, the warping of the underlying surface of Little Falls dolomite renders the suggestion of gradual diminution quite impossible; and the same reason might very well cause rapid thinning west of Little Falls.

At Middleville we measured the following section up the creek which comes into the town from the east:

SECTION AT MIDDLEVILLE

	Feet	Inches
25 Trenton limestone with Dalmanella common in lower 6 feet and Prasopora simulatrix abundant above that	60	
Hiatus	..	....
24 Thin bedded, dove limestone with irregular summit; abundant Phytopsis, and Tetradium cellulosum; typical Lowville	13	
23 Concealed	2	
22 Thin bedded, light colored, sandy limestone with abundant quartz grains; much bored by worms of large size; upper 2 inch layer a calcareous sandstone, at base of which worm tubes cease; 1 foot, 5 inches to	2	2
21 Cobbly, conglomeratic, calcareous sandstone, black to brown in color		10
20 Irregular bed of calcareous, small-pebbled quartz conglomerate; base of Lowville	1	
Hiatus and unconformity	..	....
19 Compact, very fine grained, light bluish gray dolomite	3	

		Feet	Inches
18	Alternating beds of light gray, finely crystalline dolomite and of more sandy, darker colored material; midway is a heavy chert bed, with both black and gray chert	12	
17	An irregular bed of light gray, finely crystalline dolomite, laminated and weathering to finely lined surface, filling irregularities in surface of preceding bed; 1 foot to	3	
16	Very nodular and irregular bed of gray dolomite, with many sand grains and with cherty looking plates of black, silicified sand; 5 feet to	8	
15	Chiefly very light gray, calcareous, sand rock, but with alternating seams of darker colored dolomite.	10	
14	Light bluish gray, finely crystalline, drusy dolomite; very few grains	2	8
13	Very dense, fine grained, light colored, very sandy dolomite, full of rounded grains of quartz sand; many drusy cavities	2	3
12	Porous, very light gray, finely crystalline dolomite, with many sand grains, and frequent green specks; many drusy cavities with quartz crystals in upper portion	3	3
11	Massive, gray dolomite, with many sand grains....	5	4
10	Very fine grained, mottled, light gray dolomite....	2	6
9	Dark gray, very quartzose, massive dolomite........	8	
8	Massive, somewhat porous, dark gray dolomite; sand grains fewer than in the beds beneath, but larger size	12	
7	Light gray, thin bedded, very sandy dolomite, with black streaks running through it; full of sand grains; one thin, hard, fine grained layer 4 feet above base	13	
6	Concealed, about	60	
5	Rather massive, porous, blue gray, crystalline dolomite; frequent crystalline nodules filled chiefly with calcite	4	10
4	Massive, Cryptozoon reef layer; blue gray, porous dolomite with nodules of calcite........	5	
3	Blue gray, porous, crystalline dolomite........	1	4
2	Concealed, about	25	

	Feet	Inches
1 Massive, finely crystalline to granular, gray dolomite, with large calcite nodules	3	
Interval to surface of Precambric in West Canada creek, about	50	

In this section, including the concealed interval at the base, we have a thickness of 231 feet of Little Falls dolomite, as measured from the base of the Lowville down to the level of West Canada creek, which is substantially the base of the formation. There is nothing that we could definitely correlate with the Tribes Hill limestone as already stated. The thickness here is just about half the combined thickness of the two formations at Little Falls. Since at least 50 feet have gone from the summit it seems to us clear that the thinning in this direction is not due simply to overlap, but represents a loss both above and beneath; that is that each of the two formations thins northward, and that the Tribes Hill has thinned to the vanishing point.

It will also be noted that there is here a thickness of nearly 19 feet of Lowville and that the Lowville is directly followed by the Plectambonites and Prasopora bed of the Trenton with no sign of the older beds, which in the Mohawk valley have usually been referred partly to the Black River and partly to the Trenton.

Four miles northwest of Middleville along West Canada creek is Newport, and here the most westerly of the good sections, exposing the horizon with which we are especially concerned, is found. The exposures are in the creek bed, the railroad cut just south of the depot and in Dunn's quarry a few rods west of the depot.

SECTION AT NEWPORT

	Feet	Inches
12 Crystalline, highly fossiliferous, gray limestone bands alternating with black argillaceous nodular limestone and a little shale, Plectambonites very abundant; basal Trenton	2	6
Hiatus	..	....
11 Blocky, nodular, fine grained limestone, black limestone containing Columnaria and Streptelasma; has heretofore been referred to as "Black River" but represents the Leray limestone member of the Lowville formation in Jefferson county	2	2
Small hiatus	....	....

	Feet	Inches
10 Brittle, dove limestone, of ordinary Lowville character, full of Phytopsis tubes	13	
9 Brittle, dove limestone, with occasional sand grains in the basal layer; slightly impure as shown by irregular laminations on weathered surfaces; Tetradium cellulosum occurs below summit	6	4
8 Concealed except for the surface of one layer at base, which is slightly impure dove limestone, with frequent sand grains	1	9
7 Concealed	3	
6 Thin bedded, light colored sandy limestone and calcareous sandstone; shaly partings; probable base of Lowville	4	6
Hiatus and unconformity	..	....
5 Concealed	20	
4 Massive, gray, drusy dolomite; quartz sand grains	1	6
3 Irregular, massive to thin bedded, sandy, gray dolomite; many druses above; many sand grains; certain layers mottled and laminated with black	13	
2 Concealed	15	
1 Massive, granular, blue gray dolomite, but few sand grains; Cryptozoon and much chert in lower 5 feet	8	

Here we find the Lowville thickness to exceed 28 feet, as against the 15 feet shown in the Middleville section; we have also beds intervening between the Lowville and the Trenton which do not appear in the Middleville section. But as in that we find no trace of the Tribes Hill formation, the Lowville resting on the Little Falls dolomite.

In these western sections of the Little Falls dolomite, we miss the light colored, coarsely crystalline beds which form the summit of the formation at the east. Whether they were deposited and eroded before the deposition of the Tribes Hill, or whether they change laterally into finer grained, gray beds on passing west, we are not sure. Since the formation shows no diminution in thickness it is perhaps more probable that the latter is the case.

Theresa formation

This name was given by Cushing two years ago to the passage beds and overlying magnesian limestones which occur between the

Potsdam and the Pamelia formation (upper Stones River) in the Thousand Island region.[1] The formation as defined is thin, not over 60 feet, seemed a unit and was thought to be entirely older than the Beekmantown. In its lower portion a variety of Lingulepis acuminata is abundant, while the higher beds contain cystid plates and a large, flat gastropod. These now prove to be identical with the cystid plates and the Pleurotomaria hunterensis (Cleland) which are found in the Tribes Hill limestone of the Mohawk valley, whence it follows that the upper portion of the Theresa formation in Jefferson county is of lower Beekmantown age. We are, however, of the opinion that the lower portion is properly to be classed with the Potsdam beneath as of Saratogan (Ozarkic) age and that there are two formations present instead of one. We also think that an unconformity will be found between the two, now that it is suspected, so that search can be made for it. It is, therefore, unfortunate that a name was given to the supposedly single formation. We suggest, however, the retention of the name Theresa as a designation for the passage beds which occur everywhere in New York between the Potsdam and the overlying Little Falls dolomite, since they have a characteristic lithology of their own, and should be and can be mapped separately.

Correlation of the foregoing sections

In order to bring out more clearly and concisely our ideas in regard to the sections, they are given in generalized form in the accompanying table. The Little Falls dolomite occurs in all and in fairly uniform thickness except at the extreme west where it is thinned by overlap on the Precambric. The Tribes Hill limestone overlies it in most sections, but thins westward to disappearance in the Mohawk valley; the Saratoga region seems to have been just beyond the reach of its deposits. Correlating the Tribes Hill with the typical dove limestone of division B of the Champlain Calciferous, then sedimentation would seem to have been only locally interrupted in that trough as noted in the vicinity of Ticonderoga. But, if the former is older than the latter, as is indicated by faunal evidence, then the whole of the Champlain valley was emerged while the Tribes Hill was being deposited in the Mohawk valley.

The Tribes Hill and Little Falls formations seem everywhere unconformable in New York, and we make this unconformity the

[1] Geol. Soc. Am. Bul. 19: 155-76.

Chart of sections

	NEWPORT MIDDLEVILLE	LITTLE FALLS	SPRAKERS	CRANESVILLE TRIBES HILL BROADALBIN	SARATOGA SPRINGS	WHITEHALL	TICONDEROGA
Ordovicic	Either Lowville, or other Mohawkian limestone caps each section unconformably.						
						Beekmantown Div. D (?C, ?E)	Beekmantown Div. C, D, E
Unconformity		Tribes Hill limestone	Tribes Hill limestone	Tribes Hill limestone		Unknown	absent or represented in Div. B
Saratogan	Little Falls dolomite	Little Falls dolomite	Little Falls dolomite	Little Falls dolomite	Little Falls dolomite Hoyt limes.	Little Falls dolomite	Little Falls dolomite
				Theresa formation	Theresa formation	Theresa formation	Theresa formation
				Potsdam sandstone	Potsdam sandstone	Potsdam sandstone	Potsdam sandstone
	Each section rests unconformably on Precambric.						

dividing line between the New York representatives of the Saratogan (Ozarkic) and the Beekmantown (Canadian). In the Champlain region the higher divisions of the Beekmantown occur, but they are utterly lacking in the Mohawk valley and were never deposited there. The Potsdam sandstone and the passage beds (Theresa formation) are also chiefly confined to the eastern sections, though their thinned edges appear in the easterly Mohawk sections. The Chazy is absent in all sections, the Lowville (or some even younger) limestone resting on the Little Falls, the Tribes Hill or on some later division of the Beekmantown, in the various sections included in the table.

Stratigraphic positions of the Potsdam, Little Falls and Tribes Hill formations

Saratogan series. Though the Saratogan was defined and is generally accepted as the name of the closing stage of the Cambric in America, it is now practically certain that the deposits of the series in New York are of a later date than are the formations in Missouri, Texas, Oklahoma, Wyoming and elsewhere, that Walcott and others have referred to the Upper Cambric. While there can be no question concerning the essential equivalence of the beds in the latter states, as indicated by stratigraphic position and persistence of lithologic and faunal characters, the facts are altogether different in the case of the typical New York Saratogan. Practically the same fauna, the species in many cases being identical, occurs in the middle and more western localities in America in beds corresponding to the sandstone and chert beneath the Jordan sandstone of the upper Mississippi valley section. These beds are further distinguished except, in the Great Basin, by the rather abundant presence of glauconitic or chloritic grains and by the almost constant presence of thin limestone conglomerates in their upper parts. Apparently very general sea withdrawal occurred at the close of this Upper Cambric stage. So far as known this Upper Cambric sea is scarcely represented in the Appalachian valley and certainly it did not extend into the middle and northern parts; but it spread widely in the median areas between the Appalachian and Cordilleran troughs.

The return of the waters introduced the proposed Ozarkic period of Ulrich. The new sea differed greatly from the preceding Upper Cambric sea in that it failed to cover the Rocky mountain area and in that it submerged the Appalachian and more

inland troughs and basins to Canada. In the Mississippi valley and in central Texas its deposits covered about the same areas previously held by the late Cambric sea. It is this Ozarkic sea that rather early in its history surrounded the Adirondack uplift, laying down first the Potsdam, then the Theresa and finally, when conditions had become fairly quiescent and established, the Little Falls dolomite. However, long before the close of the Ozarkic the waters were again withdrawn from New York into reconstructed Appalachian troughs, remaining also in the but slightly modified basins of the Mississippi valley.

The more essential features of the evidence on which this interpretation is based may be briefly stated as follows: (1) The stratigraphic relations of the Potsdam to the Theresa and of this to the Little Falls indicate a practically uninterrupted sequence of sedimentation. There was gradual reduction of adjacent land areas, and there may have been slight oscillations, but there is no evidence of a break in deposition nor of change in its character that may not be explained as of purely local significance. (2) So far as known there are no deposits corresponding in age to the Upper Cambric in the Mississippi valley in areas intervening between this valley and the Adirondack region; neither have any been discovered in the middle part of the Appalachian valley nor in the Atlantic province; hence there is no means of directly connecting the Potsdam-Little Falls deposits and faunas with true Upper Cambric life and sediments elsewhere. (3) The Potsdam and Little Falls are clearly recognizable in the Allentown formation (Ulrich) in central and northeastern Pennsylvania and in the lower and middle divisions of the Knox farther south in the Appalachian valley. The Allentown rests on Lower Cambric, both Middle and Upper Cambric being absent in its area. The probably equivalent Conococheague formation of the Cumberland valley in southern Pennsylvania, contains a Saratogan fauna but differs lithologically and is underlain by two Middle Cambric formations. The lower Knox is underlain by a thin Upper Cambric, considerable Middle Cambric and some Lower Cambric, the southern Appalachian Cambric section being relatively complete. Each of these Appalachian Ozarkic formations is overlain by from 1000 feet to 4200 feet of Canadian (emend. Ulrich) limestone and dolomite, represented in eastern New York by the Beekmantown. (4) The fauna so far discovered in the Sara-

togan of New York, particularly in the Hoyt limestone, is entirely distinct from that found beneath the St Lawrence limestone in the upper Mississippi valley, but some of the species occur there in the overlying calcareous and arenaceous deposits (St Lawrence limestone, Jordan sandstone and Oneota dolomite), while all of them are included in the large molluscan and trilobite faunas discovered by Ulrich in the middle divisions of the Ozarkic in Missouri. Most of them occur there in the Gasconade chert, which is the third from the top of the seven formations into which the Ozarkic in Missouri is divisible. All of these formations succeed the Bonneterre limestone and Davis shale, which carry the St Croix and Reagan fauna that is so widely distributed in the Mississippi valley, in the Rocky mountains and in Texas, and which Ulrich, chiefly on diastrophic grounds, regards as marking the closing stage of the Cambric in America. If this is not conceded then there is no sufficient reason for drawing the upper boundary of the Cambric system beneath the top of the Ordovicic — which would go back to Sedgwicks's original conception of his Cambric — nor for recognizing more than a single system in the Neopaleozoic, another in the Mesozoic and a third in the Neozoic. If the Devonic is recognized as a system distinct from the Siluric on the one side and the Waverlyan on the other then the Ozarkic is no less distinct from the preceding "Cambrian" and the succeeding Canadian system; and the Canadian is equally distinct from the Ordovicic. If the criteria relied on are deemed sufficient in any of these instances then they are equally sound and worthy of consideration in all the others.

The boundary between the Cambric and the Ozarkic as here drawn is everywhere recognizable and the contacts between the Ozarkic and the Canadian, and between the Canadian and the Ordovicic are likewise definite. This is because they are determined by diastrophism. But no one has yet succeeded in drawing a satisfactory boundary between the upper limit of the range of "Cambrian" trilobites and the lower limit of the "Ordovician" gastropods and cephalopods. In fact there is no such boundary, since the latter were well established before the middle of the Ozarkic, and Cambric types of trilobites survived through the Ozarkic into the Canadian and a few even into the Ordovicic. Of course, neither the beginning nor the closing deposits of these Eopaleozoic systems are even approxi-

mately similar in geographic distribution. There was too much oscillation for that. Indeed, it is only here and there within the great Appalachian and Cordilleran troughs that anything like a complete sedimentary record of any one of the systems is found. But these inequalities of distribution are an aid rather than a hindrance in the recognition of the boundaries, because they make them correspondingly more distinct where the breaks in the record are expanded.

The faunal distinctions marking the revised systems also are more definite and more readily apparent than are those hitherto relied on in discriminating between the Cambric and the Ordovicic.

In the trilobites and the brachiopods we use specific rather than generic types in discriminating between the Upper Cambric and the Ozarkic; likewise among the previously established conical and involute gastropods. The correlation value and use of such long-lived types is precisely as in the case of genera common to two or more of the later systems in whose discrimination, moreover, specific differences comprise a greater and greater proportion of the competent organic data. The surviving Cambric trilobites and brachiopods have then essentially the same significance in stratigraphic taxonomy that we accord to Spirifer and Atrypa, which are well developed in the Siluric and continued their existence into subsequent periods; or to genera of Ordovicic trilobites that are nearly as well represented in the Siluric.

To disregard the probability of transgressions of generic types from the earliest Paleozoic system into the next younger system is to stand in the way of progress in stratigraphic correlation and classification. The principle is recognized in the discrimination of all the later systems, why not also in the case of the American Cambric? The past practice of classifying, often without regard to stratigraphic evidence, all formations as Upper Cambric that are younger than Middle Cambric and apparently older than beds containing supposedly indubitable Ordovicic fossils, was possibly justifiable, but only so long as the faunal history of a great intervening mass of rocks remained to be accounted for. Now, however, since this old "Calciferous" hiatus has been peopled with a large mixed "Cambrian" and "Ordovician" fauna, and since we have come to understand the stratigraphic relations of most of the formations concerned in the inquiry, some other arrangement that will express the facts is desirable. We need a vehicle that will permit us to cor-

rect the misapprehensions into which the former *terra incognita* and our blind reliance on unsupported fossil evidence led us; a means of showing, for instance, the true stratigraphic relations of the Saratogan fauna as developed in New York to the Upper Cambric faunas in Missouri and Texas, or of the Dictyonema flabelliforme and the Tetragraptus zones, or the Tribes Hill and other Canadian formations to the Saratogan and later Ozarkic formations on the one side and the typical Ordovicic formations on the other. It is believed that the revised classification proposed by Ulrich accomplishes this aim. The table given on page 129, though intended to show only the relations of the New York formations discussed in this paper, gives a fair general idea of the proposed scheme.

Perhaps the most practical feature of the revision of the Eopaleozoic systems, so far as the use of fossils in their separation is concerned, is that we can say that the cephalopods and the coiled gastropods, also true cystids, became prominent for the first time in the Ozarkic, that the true graptolites, true ostracods, true Orthidae and the Asaphidae are first seen in the Canadian, and that the tabulate and rugose corals, the cyclostomatous and cryptostomatous bryozoa, the pelecypods and the crinoids are well developed in the Ordovicic but unknown beneath this system. In short, the new arrangement is in accord with, and makes available in the broader stratigraphic correlations, the apparently definite vertical distribution of many important organic types. This distribution has not been considered as it should be in the prevailing indefinite arrangement of the Eopaleozoic rocks. As hitherto conceived the cephalopods and gastropods, the Asaphidae and Orthidae, and the graptolites appear at undetermined stages in a " Cambrian " system that has no more precise top than the fortuitous first appearance of certain fossil types, arbitrarily assumed to be Postcambric, above a similarly indefinite upper limit of certain Cambric genera of trilobites and brachiopods.

Obviously, there has been no uniformity of practice. Walcott extended the lower system as far up in the section as he could recognize certain Cambric genera. Others, with the laudable but insufficiently considered intention of fixing the boundary at a well defined stratigraphic break, went farther and drew the top of the Cambric at the base of the St Peter, while others with a similar intention extended the base of the Ordovicic down to the first break beneath the introduction of the cephalopods and coiled gastropods, that is to practically the base of the Ozarkic. More commonly,

however, in areas containing Ozarkic and Canadian deposits the boundary between the Cambric and the Ordovicic has been left undecided, or it was drawn arbitrarily in the midst of what was thought to be a great, sparsely fossiliferous, transitional series of dolomites and limestones because its basal part contained surviving remnants of the Cambric fauna, and its uppermost ledges held fossils too much like Ordovicic species to be interpreted otherwise than as Postcambric.

This inharmonious practice was perhaps excusable under the prevailing state of knowledge concerning Eopaleozoic history. So long as the oscillatory character of the continental seas of this era and the consequent variable localization of their deposits were not appreciated, the formations occupying apparently similar stratigraphic positions had to be correlated, and the observed differences in their respective lithologic and faunal aspects were of course only geographic changes or merely local phases. There was also considerable excuse for individual difference of opinion as to which of the organic and physical criteria were the most deserving of confidence.

But now, since it has been learned (1) that the Presaratogan deposits in the Appalachian and Cordilleran troughs attain more than sufficient thickness, and that their diastrophic history in America fully satisfies the requirements of an ideal geologic system;[1] (2) that the great deposits of dolomite, limestone and sandstone which usually succeed the Cambric were not laid down in a continuous broad continental sea, hence that the magnesian limestones at one place may be altogether younger or older than those at another; (3) that these dolomites, limestones and sandstones are divisible or may be grouped into two distinct series, largely independent in geographic distribution and each characterized by its own physical and faunal development; (4) that each of these two series attains an aggregate thickness of over 4000 feet of calcareous deposits, hence, that each is comparable in time value to most of the systems now recognized; (5) that their independence, first suggested by diastrophic and faunal evidence, is now firmly established by the actual superposition of 4200 feet of Canadian dolomite and limestone in central Pennsylvania on fully 2000 feet of Ozarkic deposits; (6) that in the Appalachian region the whole

[1] On questionable grounds, discussed elsewhere by one of the present authors, Schuchert [Geol. Soc. Am. Bul. 20:513–22, 600–2] divides the same interval into two systems (Georgic and Acadic).

of the Canadian underlies an aggregate thickness of nearly 4500 feet of Ordovicic limestone; and finally (7) that essentially the same cycles of movement, of submergence and emergence, as are used in distinguishing four Neopaleozoic systems, also obtained in the Eopaleozoic and suggest the propriety of a similar division of the Eopaleozoic into four systems instead of two as heretofore. In view of these facts we ask: Is the present indefinite separation of the Eopaleozoic into Cambric and Ordovicic a reasonable and adequate classification? Are these divisions coordinate in rank with the Neopaleozoic, Mesozoic and Neozoic systems? Our answer to these questions is clearly anticipated in the foregoing comments and arguments.

Age of the Tribes Hill formation. A few words remain to be added respecting the age of the Tribes Hill. The formation is certainly Postozarkic, but its position in the Canadian is less easily determined. Except that we know the formation to be unconformable on the Little Falls and that the contact represents a considerable hiatus, we have only organic criteria to guide us in determining the age. That the Tribes Hill is younger than any known Ozarkic formation is satisfactorily shown by the presence of Asaphus and three or four other trilobites that are wholly unknown in Ozarkic faunas. The same is true of the Ribeirias; and the Dalmanella? wemplei also is of a type that has not been observed beneath the Canadian. With the exception of Eccyliomphalus multiseptarius, the testimony of the gastropods is less positive, very similar, though specifically distinct, forms being found in Ozarkic faunas. The gastropods described by Cleland from the upper chert zone of the Little Falls dolomite at Little Falls are clearly Ozarkic types and hence are not referred to in this paragraph.

That the Tribes Hill is Canadian (emend. Ulrich) is unquestionably indicated by its fossils; and the same evidence is almost conclusive in assigning the formation to an early stage in this period. With the possible exception of an orthoid shell, all the species so far discovered in the Tribes Hill are distinct from those described from the Beekmantown in the Champlain valley. They impress one as older. This suggestion is confirmed when we compare the Tribes Hill forms with faunas found in the Canadian in central Pennsylvania. The nearest facies — there are at least five and probably six identical species — is found in the Bellefonte, Pa. section about 3700 feet beneath the top of the Canadian. None of the succeeding faunules in the Bellefonte section are closely allied.

Relying on the fossil evidence just given it seems almost certain that the Tribes Hill is at least as old and probably is older than the dove limestone in division B of the Champlain "Calciferous." This conclusion finds further good support in the fact that Cryptozoon steeli, the principal fossil of division B, is found in Pennsylvania *above* the Stonehenge limestone which there contains the Tribes Hill fauna.

Oscillations of level

As detailed work has been carried forward in northern New York during the past few years, the evidence has been steadily accumulating to show that with a possible exception during the late Ordovicic the Adirondack region remained steadily as a land area, being sometimes an island, at other times part of a much larger land. It appears further that frequent and often very local oscillations of level effected modifications of its shore line; that the present erosion surface cuts the rocks in such wise that the surface exposures are chiefly of the thinned, near-shore margins of many of the formations; that gaps in the succession are frequent, and with much variation from place to place; and that, because of these conditions, the New York section of these rocks is very thin and very imperfect. From time to time Cushing has summarized our knowledge of these oscillations.[1] With each onward step in the detailed work, however, evidence of further, and unexpected oscillations appears; and no doubt we are, even now, acquainted with but a small proportion of them. Nevertheless our present understanding of them should be summarized.

To begin with, no part of New York was submerged during the Cambric. Lower Cambric deposits do occur locally within the eastern edge of the State south of the Champlain valley but it is highly probable that these are masses originally laid down in a trough farther east and which were subsequently thrust westward to their present position. The somewhat doubtful Middle Cambric sediments found in Stissing mountain near Poughkeepsie probably owe their present location to similar thrusting. True Upper Cambric (St. Croixan) rocks are entirely unknown within the State. Neither have such been found to the

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[1] N. Y. State Mus. Bul. 77, p. 51–65.
N. Y. State Mus. Bul. 95, p. 386–94.
Geol. Soc. Am. Bul. 19:175–76.

east in the New England States, nor to the west as far as Michigan and Indiana. They seem to be absent also in the Appalachian folds north of Virginia. Evidently New York formed part of a very large land area during the Cambric ages. The first important and unquestionable Paleozoic submergence of the southern flanks of this land occurred in the early part of the succeeding Ozarkic period. This was the Potsdam or Saratogan submergence.

Potsdam deposition commenced in the Champlain trough, toward its northern end, working southward in that trough, and also working westward up the St Lawrence trough. In its lower portion it was probably a continental deposit, but the upper portion carries a marine fauna, and this continues on through the passage beds into the Little Falls dolomite which lies directly above. The deposition was continuous and unbroken, so far as we know, from the one formation into the other. The subsidence in the St Lawrence trough reached as far west as Kingston during the Potsdam and probably but little farther. From Kingston it extended southward at least to some point in the valley of Black river. To how large an extent western New York was submerged we do not know positively. It seems likely, however, that a considerable expansion of the upper St Lawrence trough occupied the north central part of the State and probably covered also the western part of New York and the central part of Pennsylvania. For various reasons which can not be discussed at this time, it seems unlikely that this western lobe of the Saratoga sea connected with the eastern or Champlain lobe across the southern part of New York prior to the closing stage of the Potsdam. In this and the transition stage the highly emergent parts of the Adirondack uplift which now became an island, had been much reduced by erosion and general subsidence; and the supply of clastic matter consequently was much less during the succeeding Little Falls dolomite stage. However, just preceding the latter, warping occurred which caused reemergence of the northern and western flanks of the island and restriction of the sea to the Champlain trough on the east and the Mohawk basin on the south. The latter extended southward to northern New Jersey where its deposits are recognized in the lower part of the Kittatiny dolomite; and thence in a southwesterly direction through central Pennsylvania. Gastropod faunas found at Beauharnois near Montreal, near White-

hall, N. Y., in central Pennsylvania and in northern Virginia, leave little doubt that this sea extended down the western side of the Appalachian valley to the Mississippi valley where the same species are found in the middle formations of the Ozarkic system.

A thinned edge of the upper Potsdam runs westward into the Mohawk valley, but thins out to zero rather rapidly, letting the Little Falls dolomite down on the Precambric. It is thought that along the Mohawk line the Potsdam shore had a southwesterly trend, or rather a trend more to the south than the present Precambric margin, the two meeting at an angle; east of the meeting point the Potsdam appears underneath the Little Falls, while west of it the Potsdam is either absent or erosion has not yet cut down to it. This involves the assumption that the Little Falls subsidence covered more of the southern part of the old land area than did the Potsdam, so that, within the Potsdam zone there would be a strip of territory with the Little Falls resting on the Precambric. In some localities there is direct evidence that this actually occurred, and it was likely true of much of the southern and eastern parts of the Adirondack border.

In the Thousand islands region we find merely the thinned edges of the marine Potsdam and Theresa formations with no sign of the Little Falls dolomite. However, since these were laid down in the extreme westerly portion of the St Lawrence trough it is theoretically possible that their deposition occurred while the dolomite was being deposited along the Champlain and Mohawk lines. But there is no positive evidence that such a condition obtained. On the contrary, according to the trend of the scant faunal evidence and the probabilities suggested by general disastrophic considerations the lower or typical Theresa on the west flank of the Adirondacks is essentially contemporaneous with the transition beds on the east side; and deposition was prohibited by emergence on the west side when the Little Falls was being laid down in the Champlain and Mohawk valleys.

Following the Little Falls deposit, warping and differential uplift ensued, causing the shore lines to retreat from the district and resulting in the unconformity at the top of the Little Falls. There was some wear also since the summit is uneven and the Tribes Hill rests on different beds of the Little Falls; and, the returning waters assumed a different arrangement, with a more diversified shore line.

Beekmantown depression commenced with the Tribes Hill de-

posit, which nearly everywhere in the Mohawk valley rests on the Little Falls. In the Black river valley, where the Little Falls is absent, it rests on the Theresa formation. It is absent at Middleville and Newport, in the West Canada creek valley, showing that there, at least, it did not extend as far northward on the Adirondack oldland, as the Little Falls did. It is absent also at Saratoga, indicating that there also we are beyond its shore line. The exact equivalent of the Tribes Hill seems not to occur in the Champlain valley. At any rate its peculiar fauna has not been observed there. Apparently it is older than the fine grained limestone of division B with which the revised Beekmantown begins in the Champlain valley. Judging from the evidence now available the Tribes Hill submergence formed a geographic pattern quite different from that of the preceding Little Falls sea. The latter covered the southern and eastern flanks, the Tribes Hill occupied more limited embayments on the southern and western sides of the Adirondack area. The depression at the west was short-lived, uplift following with increasing eastward tilting, giving rise to long continued submergence of the Champlain valley. By the close of Tribes Hill time the uplift involved all the Mohawk region proper, the remaining divisions of the Beekmantown limestone being confined to the Champlain valley trough and its northern and southern prolongations. The upper Beekmantown is found to the north in the Ottawa valley. To the south Beekmantown deposits are recognized at intervals through southeastern New York, New Jersey and Pennsylvania. Although the Beekmantown is of extraordinary thickness in the last state (2000 to 4200 feet) even the thickest sections still indicate occasional interruptions in sedimentation and probably withdrawal of seas.

At the close of the Beekmantown uplift again occurred, producing the unconformity between it and the Chazy, in the Champlain valley.

We have evidence also of a number of hitherto unsuspected oscillations of the general region during the succeeding Black River and Trenton times. Since, however, we are here concerned chiefly with the lower formations, those are left for discussion elsewhere.

ON THE SYMMETRIC ARRANGEMENT IN THE ELEMENTS OF THE PALEOZOIC PLATFORM OF NORTH AMERICA[1]

BY RUDOLF RUEDEMANN

We wish to present certain facts indicating that the structural development of eastern North America has taken place in such a fashion that a notable symmetric arrangement of its elements has resulted.

This arrangement becomes especially distinct when the large area of Paleozoic rocks extending from the Canadian protaxis southward is considered by itself. This area, which is roughly bounded on the west by a line connecting the head of Lake Superior with the Ozarks and on the east by a line inclosing the Adirondacks and Appalachia, we may for convenience term the *Paleozoic platform of North America.* It corresponds in its relation to the Canadian shield with that of the "Russian platform" of the European geologists to the Baltic shield. A glance at the geologic map of North America will show that this platform is a direct southward continuation of the Canadian shield or protaxis and bounded by southward converging lines that are direct continuations of the boundaries of that shield[2] [*see* chart II, where the line M-N indicates the southern boundary of the Canadian shield A], as described by Suess and Willis. In the west the platform, like the Canadian shield, is separated from the Rocky mountain area by the north-south transcontinental depression that extends from the Gulf of Mexico to the mouth of the Mackenzie river and is occupied by Cretaceous and Tertiary rocks.

Chart II shows that the Canadian shield and its Paleozoic platform together form a body strikingly similar in its outlines to the whole continent, a fact that can not but suggest that the "Leitlinien" of this large epeirogenic element and the whole continent stand in genetic relationship.

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[1] Submitted April 1909.

[2] The Mesozoic and Cenozoic embayment of the Mississippi Valley is, in this discussion, left out of consideration, because of younger age; likewise the belt of Carbonic rocks to the west and southwest of the Ozarks, that forms the outer slope of the western arm of the platform, roughly corresponding to the area of metamorphic rocks on the opposite slope of the other arm, and properly belonging to the transcontinental depression.

In comparing the sketch map, chart I with the diagram [chart III] in which separate shading brings out the elevated and depressed regions, it is seen that on either side of the Canadian shield or protaxis [A], there stand out, like cornerstones, two separate Precambric areas, the Isle Wisconsin [D_2] and the Isle Adirondack [E_2] in quite symmetric positions. Each has its extension connecting it with the protaxis in symmetric position, that of the Isle Wisconsin being directed northeast (partly submerged by Lake Superior), that of the Isle Adirondack northwest. From each of these extensions there runs outward, along the margin of the shield, a deep depression, the Lake Superior basin [D_1] and the St Lawrence basin [E_1]. The latter is less distinct through the disturbing influence of the Appalachian folding and probably much obscured by extensive overthrusting from the southeast along " Logan's line." The effect of Appalachian folding by crushing in one side of the symmetric structure here set forth, will be discussed more fully in another chapter [*see* p. 145.]

From each of these cornerstones there extends southward like an arm, a broad belt of Precambric and early Paleozoic rocks, nearly the full length of the continent. The western arm can be traced by the great southward extension of the Precarbonic rocks of Isle Wisconsin to near the neighborhood of Burlington, the Siluro-Devonic inlier along the Mississippi above its junction with the Missouri and the large Precambric-Cambro-Siluric inlier or uplift of the Ozarks in Missouri and Arkansas[1] [D_3]. Its " Leitlinie " is shown in red overprint in the line passing from D_2 through D_3. The eastern arm [E_2–E_3] has been badly overridden, broken up and forced inward by the tangential pressure that has produced the Appalachian folds. It is, nevertheless, still easily recognized in the belt of Precambric and Precarbonic rocks, extending south and southwestward from New York as far as Alabama.

The two arms have later been somewhat disturbed and obscured, especially the western one, by the breaking down of certain portions south of Isle Wisconsin, where the Carbonic

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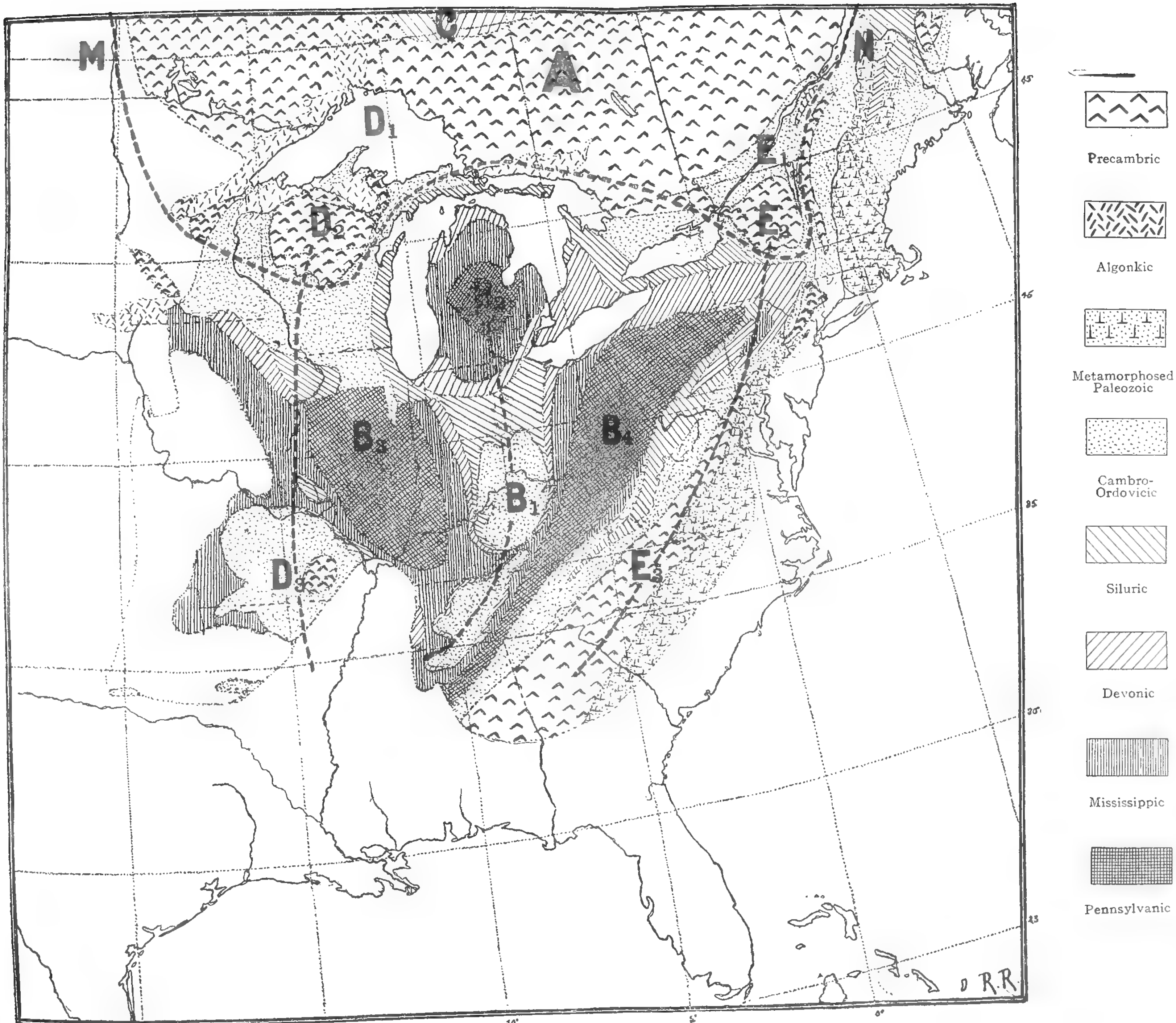
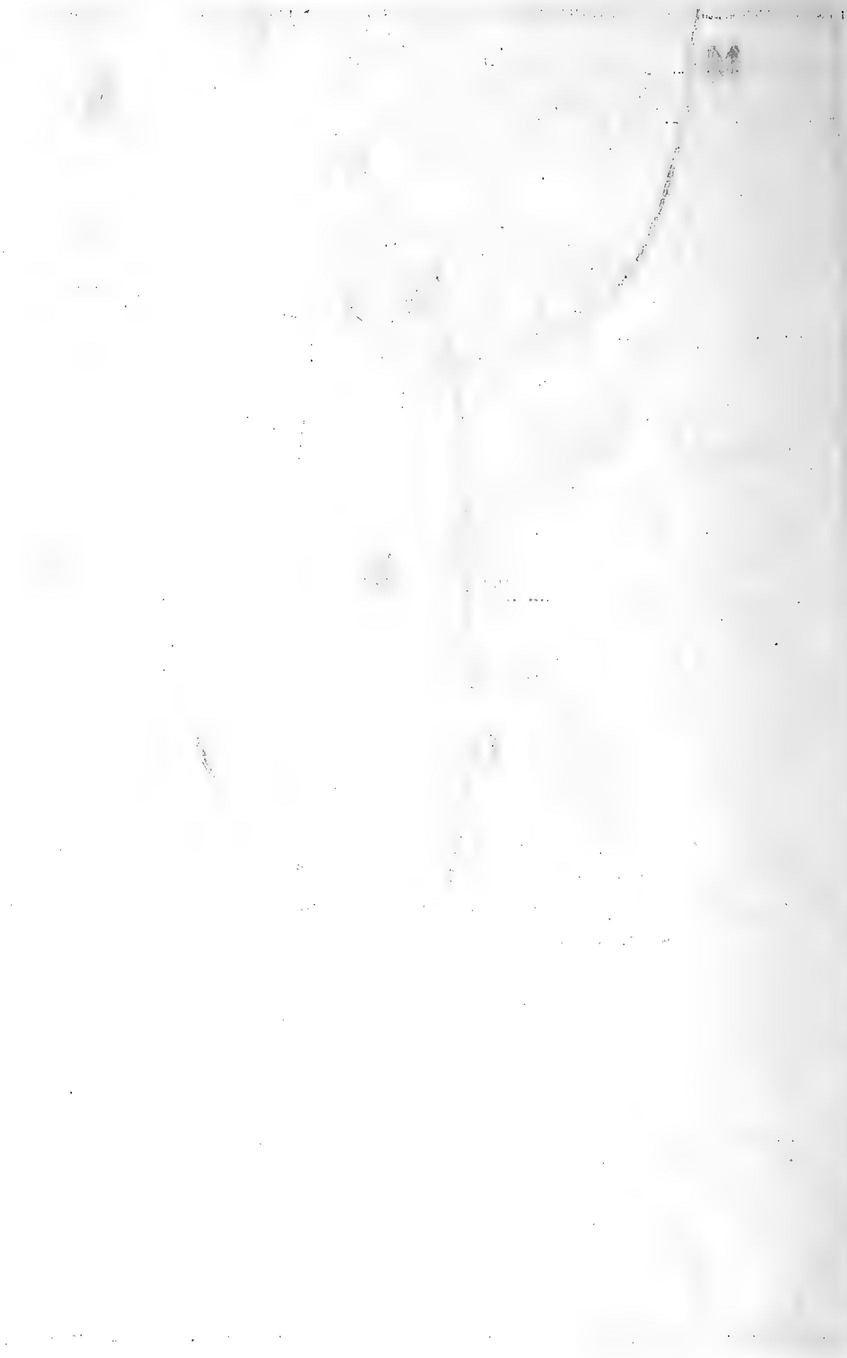
[1] The Ouachita mountains in Arkansas probably represent, according to Dr Ulrich's description [in Preliminary List of Papers, Am. Geol. Soc. 21 Meet. 1908, p. 21] and as already indicated by their strike, a different element and will, for this reason, be left out of the discussion for the present.

Chart I



GEOLOGICAL SKETCH MAP OF THE EASTERN UNITED STATES

MN southern boundary of Canadian shield A. D_2 and E_2 the symmetric Isles Wisconsin and Adirondack. D_1 and E_1 the adjoining marginal depressions of the shield. D_2-D_3 guide line of western arm of platform. E_2-E_3 that of the eastern arm. D_3 Isle Ozark. E_3 Isle Appalachia. B_1-B_2 guide line of axis of eastern basin. B_1 Cincinnati geanticline. B_2 Michigan basin. B_3 and B_4 symmetric subbasins



has transgressed it, and the eastern one by the submergence of portions southeast of the Adirondacks and by extensive folding. In their original position the two arms may be conceived as approaching each other somewhat in the south, although not nearly so much as they do now, in consequence of the forcing inward of the eastern arm, for if the considerable shortening of the Eastern basin indicated by the Appalachian folds, is taken into account and the basin spread out to its original width, the eastern arm would probably take a position fully corresponding to that of the western.

These two arms bound a large basin [B of chart II], the "Paleozoic eastern basin," now occupied by the basin of Ohio and the Great Lakes. In the middle of this an elongated low elevation formed, now indicated by the Cincinnati and Nashville "uplift."

The axial position of this uplift [*see line* B_2–B_1 on chart I] suggests that it may partake of the nature of the "geaniticlinal median"[1] that according to Haug[2] forms along the median line of a geosyncline preparatory to more extensive folding. The southern portion of the uplift which according to its normal position to the basin and the Precambric arms, should extend due south, has been affected by the Appalachian folding and twisted into a southwest direction. As a result of the warping of the axis of the basin, two separate symmetric basins have been formed,[3] one, the Eastern Interior, and the other, the East Central basin. On account of the approach of the Precambric arms in the south, these basins do not extend north and south, but extend symmetrically to northwest and northeast. The Ohio river from the Pennsylvania to the West Virginia line flows along the axis of the eastern basin.

The northern portion of the Paleozoic platform that lies to the north of the Cincinnati geanticline assumed the aspect of a separate subcircular basin, typically indicated by the Michigan coal field and the locations of Lake Michigan and Lake Huron. It also

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[1] Dana clearly recognized this uplift as a geanticline.

[2] Haug, Émile. Soc. Géol. Fr. Bul. 28, ser. 3. 1900. p. 617, and *id.* Traité de Géologie I. 1907. p. 164.

[3] Dana [Areas of Continental Progress in North America, etc., Geol. Soc. Am. Bul. 1890. 1:41], recognizing the importance of the regions of shallow seas represented by the Cincinnati uplift and the Precambric region of Missouri as regards rock-making, has distinguished these basins by the terms here used.

lies symmetric to the whole arrangement and with the Cincinnati uplift it is on the line of symmetry. It is possible that this Michigan basin, instead of being an independent depression, originated from the same warping force as the Cincinnati uplift, being the result of a longitudinal oscillation of the axis of the same geanticline, comparable to those more intensive longitudinal oscillations of the axes, which have been observed in some of the Alpine folds [*see* Haug, Traité p. 211]. The Canadian geologists, however, have claimed to find the influence of the Cincinnati uplift extending from the west end of Lake Erie further north to Lake Huron. In this case it would seem that the Atlantic pressure had affected the entire extent of the uplift [*see* p. 145] giving it a direction subparallel to the Appalachian folds, and the Michigan basin would have to be considered as independent of the Cincinnati uplift, a view distinctly not supported by the general distribution of the formations around the basin.

The development of these symmetric structures may have taken place as shown in charts II and III. In chart II the Canadian shield A and its Paleozoic platform are outlined, the two separated by the line M-N. First then, an extensive depression affected the middle portion of the platform producing the Paleozoic eastern basin B, and leaving two long embracing arms standing, the western one D and the eastern one E. A slight depression had also taken place in the northern slope [C] which finds its expression in the Hudson Bay embayment. Since this and the eastern basin lie with their longitudinal axes on the same line (meridian), the idea that they may be expressions of the same warping movement, is worthy of some consideration. In its favor could be mentioned the fact that a path of migration is postulated along this line for the Niagaran fauna by Weller and a Devonic embayment by Schuchert. It will be noticed [*see* chart II] that the Hudson Bay Devonic embayment [C] and the Michigan basin approach so much that only a relatively narrow Precambric belt separates them, upon which, moreover, still a small Paleozoic outlier (n.e. of Georgian bay) remains. It is therefore quite probable that temporary depressions extended there across the protaxis, and that the resulting Siluric and Devonic rocks have disappeared again by erosion.

Chart III illustrates the changes which next took place in the two arms and in the inclosed basin. The arms were broken

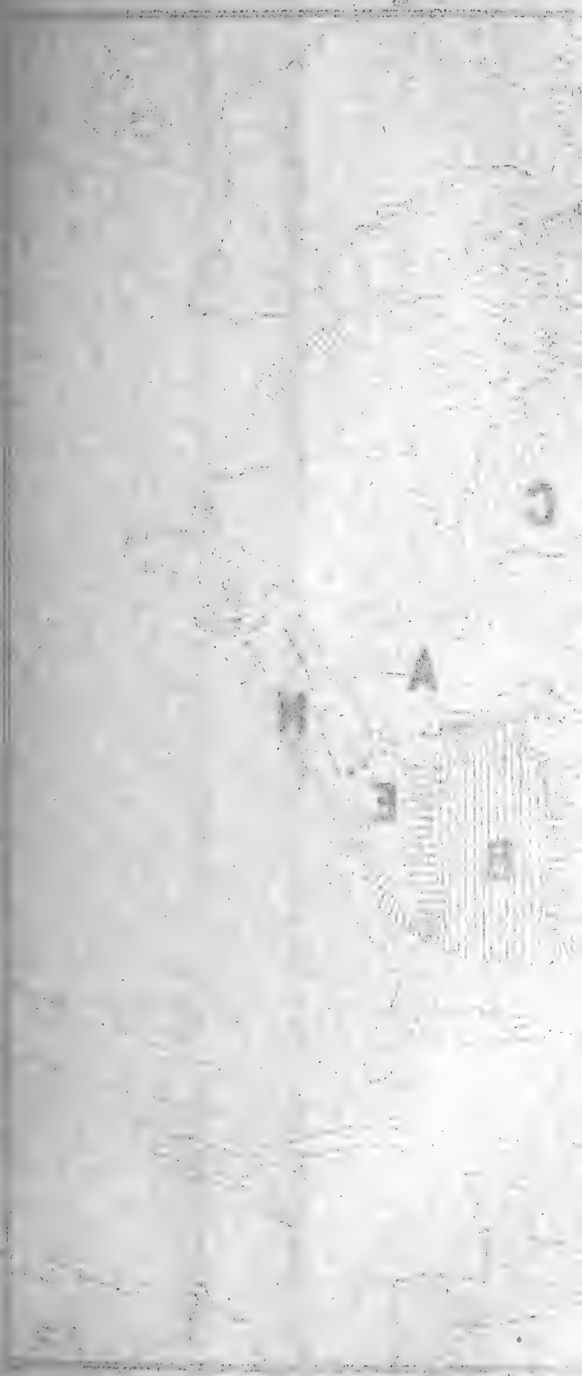


Chart 2

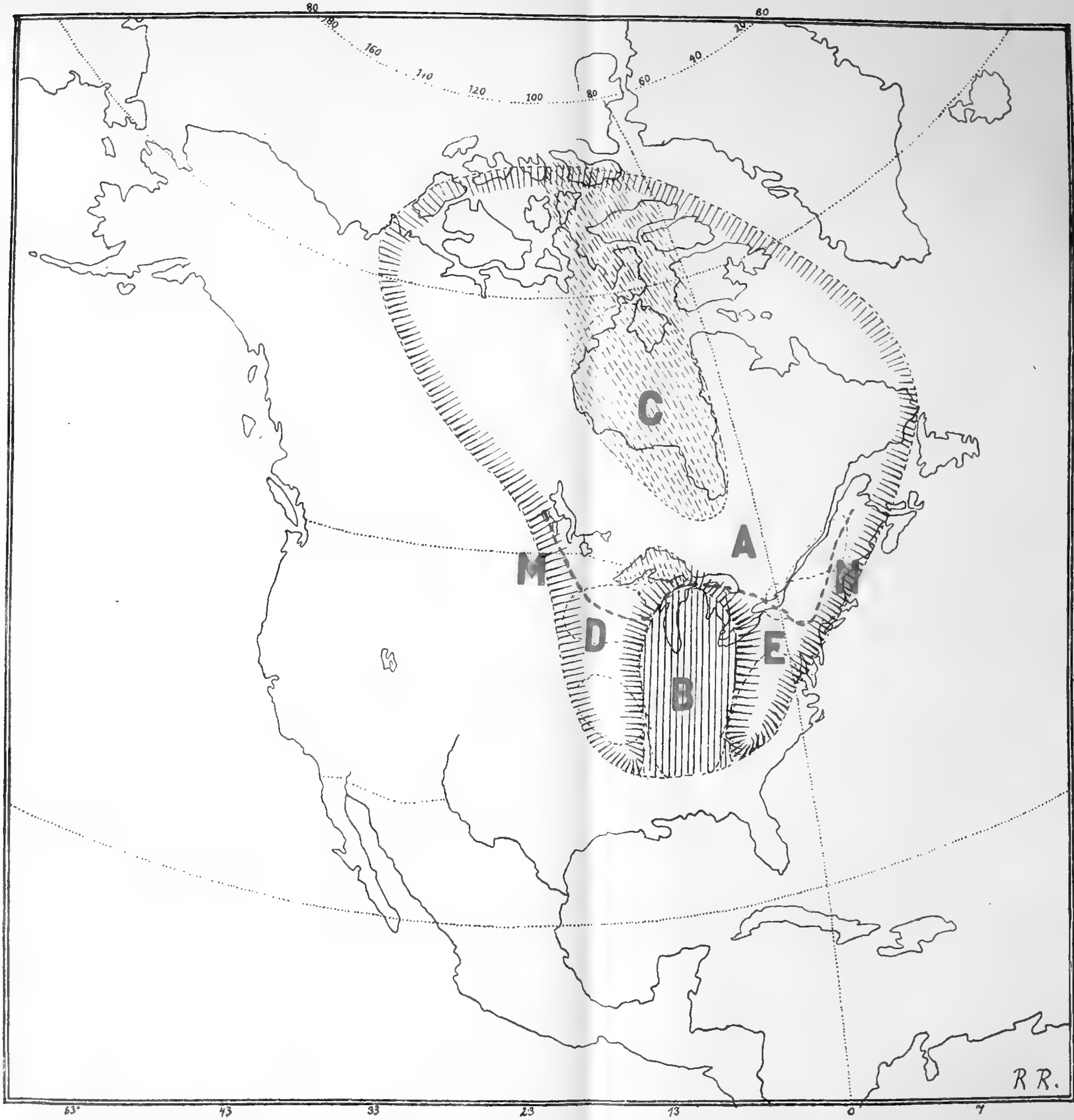
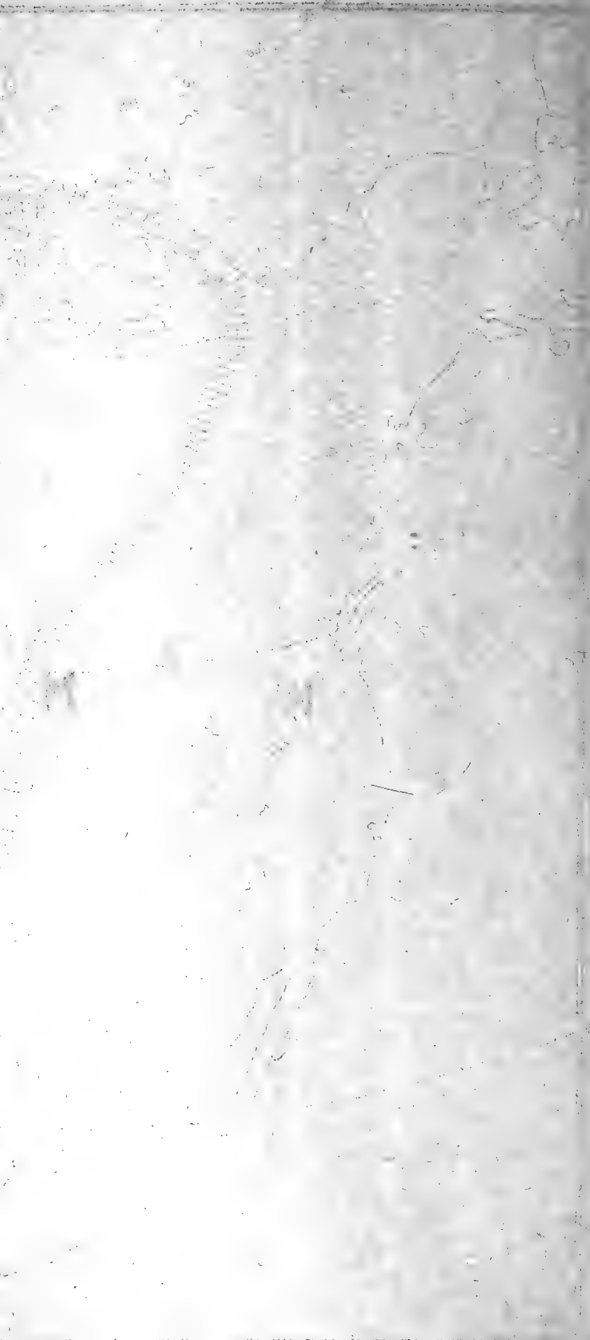


Diagram of the Canadian shield A with Paleozoic platform D B E. M N southern boundary of shield. C Hudson embayment. D western arm of platform, E eastern arm, B inclosed basin



up, with the result that on either side two principal isles, Isle Wisconsin [D_2] and Isle Ozark [D_3], Isle Adirondack [E_2] and Isle Appalachia [E_3] were formed. These isles are distinctly paired. On either side between the Canadian shield and the first isle a depression formed, the Lake Superior basin [D_1] and the St Lawrence basin [E_1], and other depressions between the first and second isles.

In the Paleozoic eastern basin a broad low anticline, the Cincinnati-Nashville parma [B_1] arose,[1] exactly in the axial line of the depression and in continuation of this line of elevation the northern part of the basin sank down into an axial basin, the Michigan subbasin [B_2]. On either side of the parma, between the latter and the Precambric arms, two basins, the East Central [B_3] and the Eastern Interior basin [B_4] were formed, in such an arrangement that they converge southward and are exactly symmetrical to the axial line of the eastern basin.

Chart IV illustrates the effect of the sub-Atlantic pressure, the cause of the Appalachian folding and overthrusting. This stress crushed or crumbled this symmetric structure from the southeast, its influence being felt in the whole eastern portion of the area. Following Claypole's earlier estimates, Willis, [Geol. Soc. Bul. 1907, 18:404] remarks that "it is a moderate statement to say that during the Appalachian revolution that portion of the continent southeast of the Cumberland Plateau rim moved northwestward at least 50 miles."[2]

On account of its oblique direction to the north-south axis of the Paleozoic eastern basin, the stress reaches deepest into the latter in the south, where it has clearly turned the Nashville portion of the Cincinnati-Nashville parma aside. It further

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[1] Suess has termed such broad warpings "parmas."

[2] Dr Willis arrives at this estimate in the following way: It is well established that the folding of the Paleozoic strata in the Appalachian zone corresponds to a narrowing of the zone by 35 miles or more — that is, the Blue ridge approached the Cumberland plateau from a distance of 100 miles to within 65 miles. The general effect may best be described as a composite overthrust from southeast toward northwest. Keith's recent investigations show that overthrusts of equal or greater displacement traverse the gneisses of the Smoky mountains. Hence it is a moderate statement to say that during the Appalachian revolution that portion of the continent southeast of the Cumberland Plateau rim moved northwestward at least 50 miles.

lengthened the Eastern Interior basin, and extended it into southeastern New York, or considerably farther north than the opposite East Central basin. Moreover, it may have produced secondary depressions east of the Michigan basin, which have finally found expression in Lakes Erie and Ontario. The principal facts suggesting the latter view are the general parallelism of these lake basins with that portion of the Appalachian folds southeast of them [1] whence the push came. It should, however, in this connection be taken in account, that it can have been but the last stages of Appalachian folding that produced the gentle down-warping of these basins, since the outwardly convex strike of the earlier Paleozoic formations (best seen at the west end of Lake Ontario) shows that this was an elevated region until at least Devonic time. It is therefore quite possible that these depressions are the counterparts of the late (early Tertiary) domelike warpings in western Pennyslvania [2] and southern New York, to which their longitudinal direction clearly corresponds.

The joining of the Appalachian folds that die out in southern New York by a new north-south system of folds in eastern New York, brings the folded region close against the Adirondack isle and produces another depressed "Vorland," the Champlain basin. The Ottawa-Montreal basin that corresponds in its position and also in its form, in surrounding the north side of the Adirondack isle, to the Lake Superior basin, has also been much encroached upon by the westward pressure of the folded region and no doubt to no little amount by extensive overthrust.

It will be seen that with the conception here presented of the geologic development of the eastern United States, the Great Lakes fall, by the first impetus to the formation of their basins — omitting the later accessory agencies, as glaciation and preglacial drainage-lines — into three groups, viz:

a Lake Superior, originating from the breaking down of one of the arms of the Canadian shield.[3]

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[1] By drawing a straight line connecting the folds from the Tennessee-Virginia line to the Pennsylvania-New Jersey line, one obtains a line that indicates the general direction of this portion of the folds, and that line is parallel to the two lake basins.

[2] *See* Campbell, M. B. Geol. Soc. Am. Bul. 1903. 14:277.

[3] The Lake Superior basin clearly antedates all the others, at least with its western arm which rests in Algonkian rocks that indicate a very early depression in the Canadian shield.

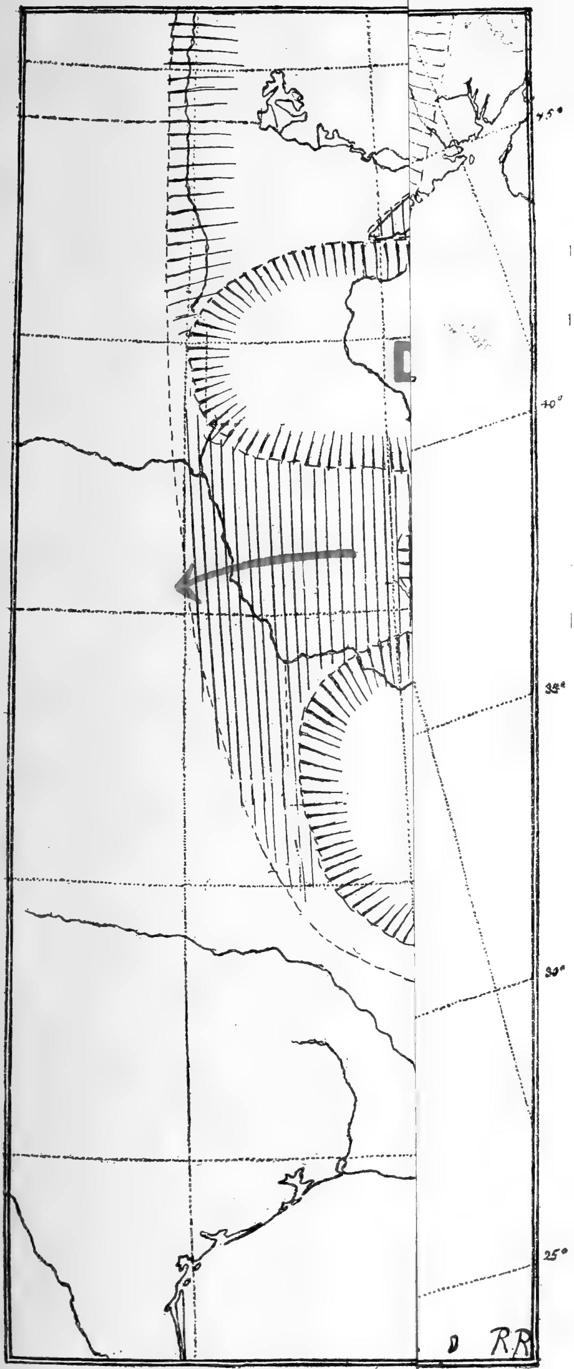


Diagram to show events on southern ing as on

Chart 3

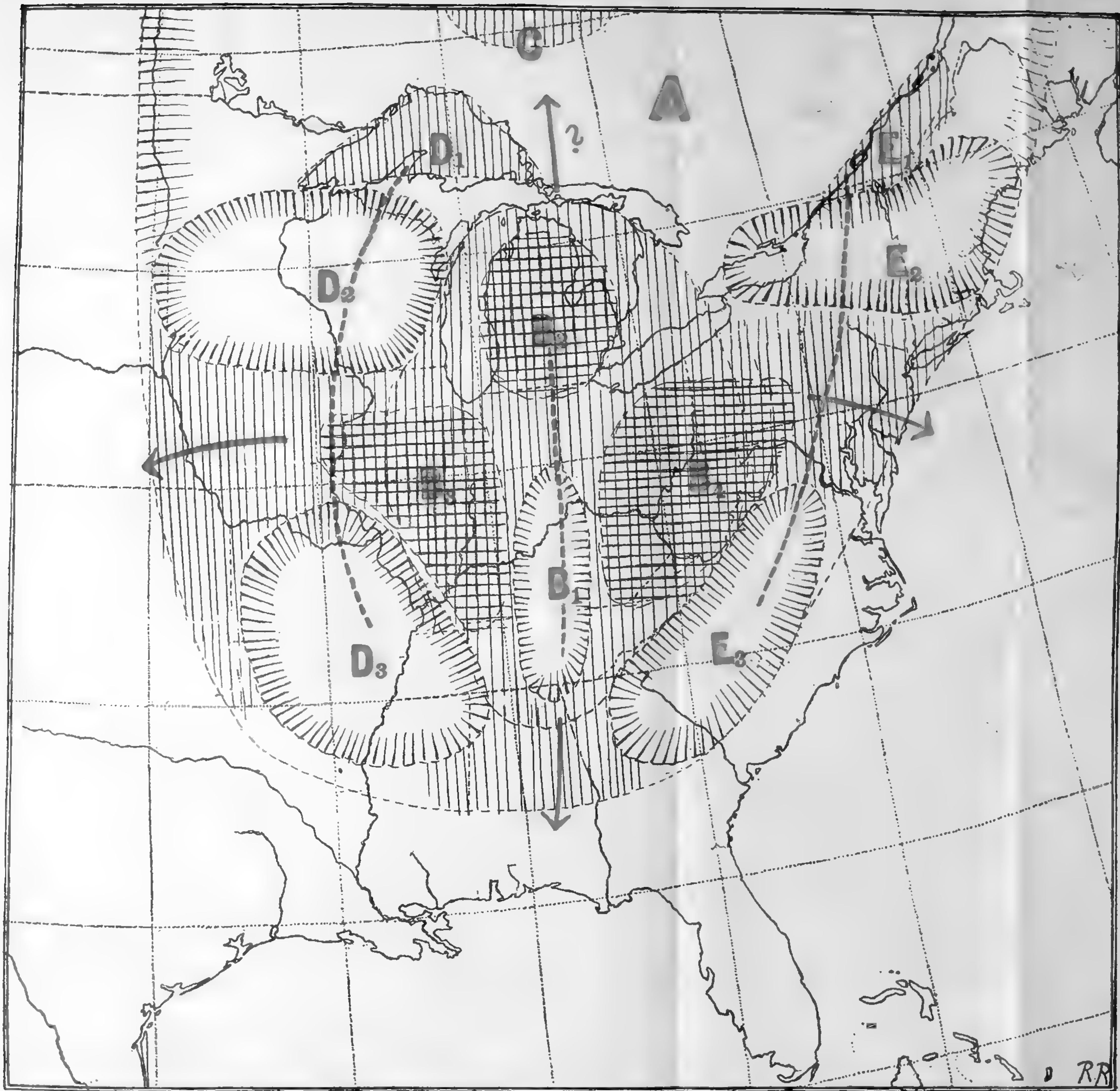
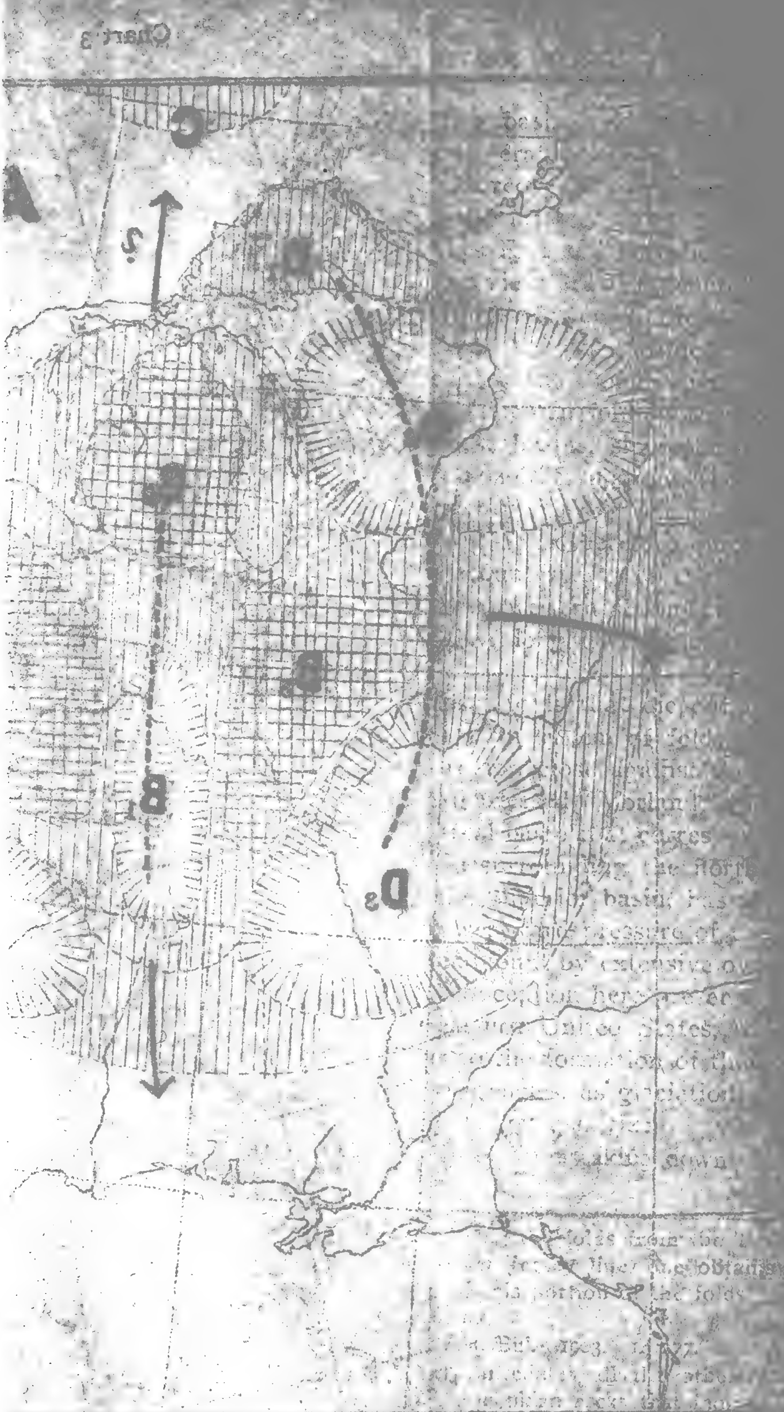


Diagram to show events on southern slope of North America still without interference of Atlantic pressure. Lettering as on chart 1. Arrows indicate main outlets of basin B.



b Lake Michigan and Lake Huron. Their location and form correspond to the Michigan basin, where they roughly follow the Devonic belts.

c Lake Erie and Lake Ontario, either depressions originating from the action of the Atlantic tangential pressure, or counterparts of later warpings in the upper Ohio basin and western New York.

We have thus far left out of consideration the Appalachian basin or "geosyncline" which occupies a narrow strip on the west side of Appalachia [chart IV] and is continued northward through New York and Vermont into Canada. It has later become the site of the Appalachian folds. Ulrich and Schuchert[1] have clearly shown that this basin became early subdivided by longitudinal and transverse barriers into a number of smaller basins. In their directions these barriers foreshadow the later, more intensive Appalachian folding, and are early indications of the influence of the pressure acting from the Atlantic basin upon and through Appalachia. It is certain that the Appalachian basin itself which became the site of the intense folding resulted from the Atlantic pressure upon Appalachia, due to suboceanic spread. It is therefore a foreign element, so to say, in the geologic history of the Palezoic platform which, however, has strongly obscured the original symmetry of the latter. While all changes here noted on the platform are of epeirogenic character, the Appalachian folds are an orogenic feature.

While in general the isles have emerged in Paleozoic times and the basins have been submerged, there have been continuous changes in the amount of emergence and submergence. This fact becomes especially manifest through Professor Schuchert's paleogeographic maps, as far as they have appeared in print, and it is probable that these subsidences and elevations took place in rhythmic pulsations.

With all these continuous changes, however, the sum total of the elevations of isle Wisconsin, isle Adirondack, Ozarkia and Appalachia has been greater than that of the depressions and they represent, therefore, positive elements of the continent in the sense used by Willis[2] while the depressions are negative elements in which, however, in some zones, as in the Cincinnati uplift, the algebraic sum of the unconformities and sediments may approach zero. The most conspicuous negative element is the Appalachian basin with its immense sedimentation.

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[1] N. Y. State Mus. Bul. 52. 1901. p. 633.

[2] Willis, Bailey. Geol. Soc. Am. Bul. 1907. 18:389.

The symmetry of arrangement of the platform is likewise but a surplus of symmetric features in the general structure over many asymmetric details in the different stages through which the platform has passed. This again is well shown by the charts of Professor Schuchert. It will be seen that at times the Nashville uplift was joined to Appalachia, and the Easter Interior basin moved northward, while the East Central basi was divided by a secondary peninsula (Kankakee) and Ozark joined to a vast western tract. But at the same time the t arms of the platform with their northern isles Wisconsin Adirondack (as peninsulas) and the southern land bodies Ozarkia and Appalachia remained distinct elements ar wise the Mediterranean basin remained defined in its outline.

The main outlets from the Paleozoic [*see* chart III] eastward between the Isle Adirondack and Appalach westward between Isle Wisconsin and the Ozark upl southward between Ozarkia and Appalachia. The Wi and Adirondack isles have apparently been frequently a to the protaxis. This becomes especially manifest in t of the Adirondack isle, where the Beekmantown, Chazy, Lowville and probably also Black River format not cross the connecting Frontenac axis. The St Lawre pression, however, frequently became an important high y of migration (as in Beekmantown, Onondaga and Hamilton times) through its southward connection, by different straits, at different times with depressions between the Isle Adirondack and Appalachia [*see p. e.* Schuchert's map of Onondaga time].

There are facts available that indicate approximately the time when the symmetric arrangement of the Paleozoic platform took place. As we have noted before, Algonkian sedimentation took place around Lake Superior [*see* chart I] but aside from this somewhat independent depression, the whole platform was, according to Walcott's investigations,[1] above sea level until Upper Cambric time, with the exception of the Appalachian geosyncline. The relation of the Upper Cambric deposits to the Isles Wisconsin and Adirondack would indicate that in this period the separation of the Paleozoic eastern basin and of the inclosing arms, took place and probably also the beginning of the breaking up of the arms. The Isles Wisconsin and Adirondack, Ozarkia and Appalachia have

[1] *See* pl. 2, 3 of Walcott, U. S. Geol. Sur. Bul. 81, 1891.

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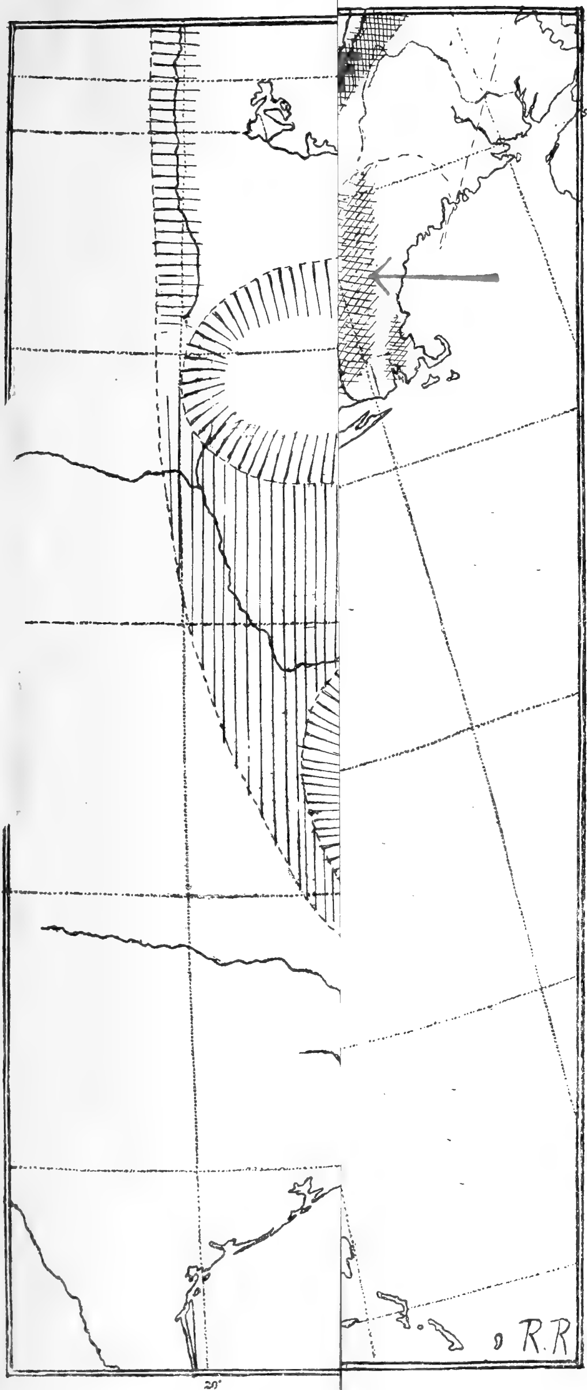

Diagram to show results o 4 and geanticline B_1.

Chart 4

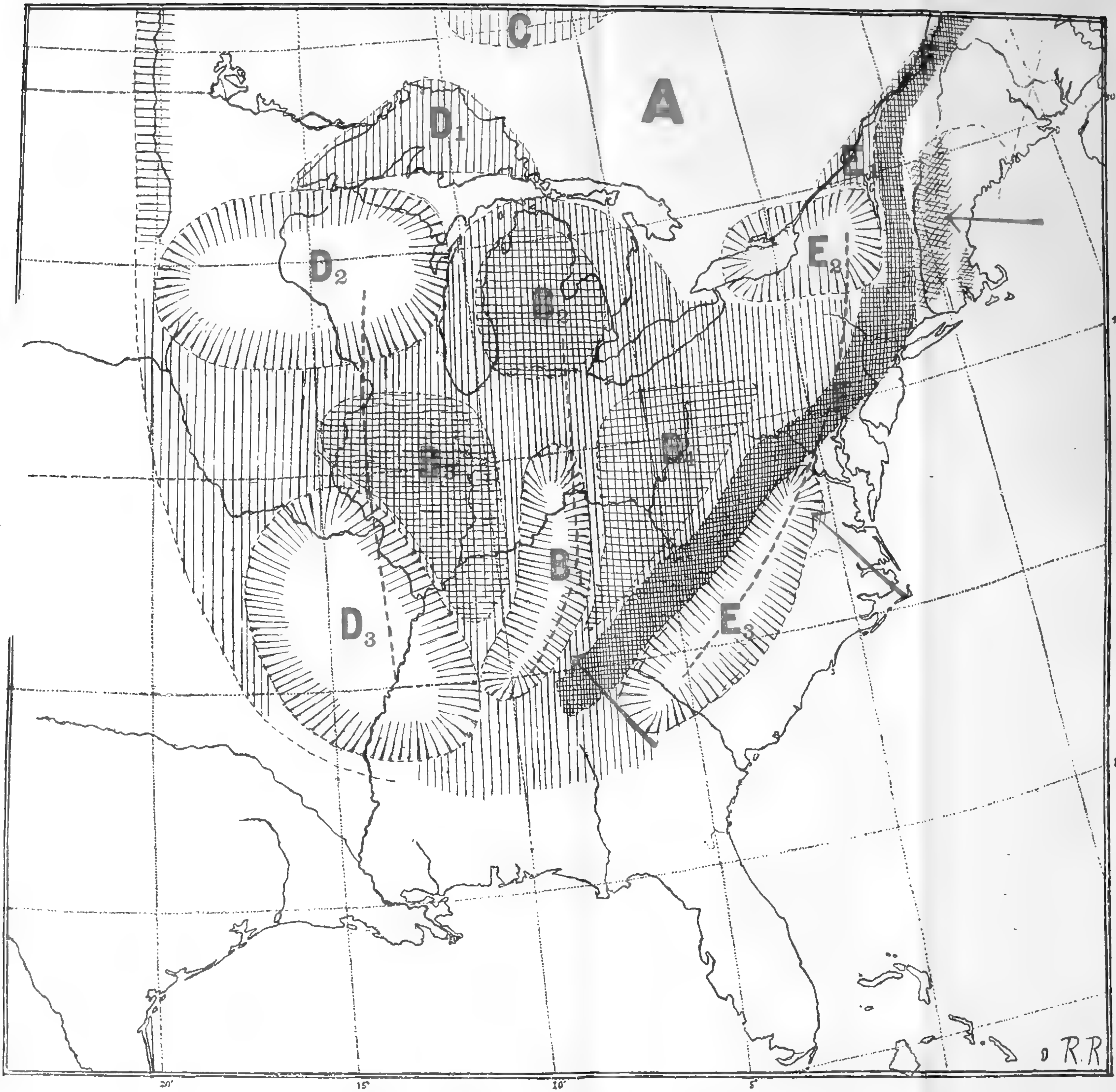

Diagram to show results of Atlantic pressure (indicated by arrows) on eastern arm E_2-E_3, subbasin B_4 and geanticline B_1. F belt of folding through Atlantic pressure

remained above the sea since the end of the Lower Siluric. In Upper Siluric time the Cincinnati parma had become a prominent feature, although the Cincinnati and Nashville parts of the same were again separated repeatedly, as in Hamilton and Mississippian times, by the submergence of the middle part. In Carbonic (Mississippian and Pennsylvanian) times all the subdivisions of the platform distinguished above, were fully developed. Since then the platform has remained land, with the exception of the Mesozoic Mississippi embayment.

Summary

The writer endeavors to point out:

1 That the Paleozoic platform of North America extending south from the Canadian shield, forms, together with the latter, a structural element of the continent, that is similar in outline to the latter.

2 That the Paleozoic platform exhibits a symmetric arrangement of its parts. This symmetric arrangement consists in the presence of a median basin (Paleozoic eastern basin) that is flanked on both sides by broad elevations, extending southward from the Isles Wisconsin and Adirondack which possess symmetric positions with reference to the Canadian shield. Ozarkia and Appalachia, the two remaining portions of elevations, hold like symmetric positions.

3 The axial line of the Paleozoic eastern basin is occupied by the Cincinnati-Nashville parma and the Michigan subbasin. The former divides the Paleozoic eastern basin into two similar and symmetric basins, the Eastern Interior and East Central basins.

4 The disturbing factor has been the Atlantic pressure, which pushed the eastern arm in and produced the Appalachian basin folds, its effect reaching as far as the Nashville uplift.

ORIGIN OF COLOR IN THE VERNON SHALE

BY W. J. MILLER

For over 50 years the subject of the origin of colors in rock formations has been much discussed and many explanations have been offered. Of the early papers that by Maw[1] in 1868 is perhaps the most able and comprehensive. In 1879 Julien[2] published a paper which contains a discussion of the origin of red formations. In 1899 Russell[3] ably treated the subject of subaerial rock decay and color origin in certain rocks. His paper gives a good summary of the views expressed by earlier writers. In 1908 Barrell[4] gave an excellent discussion of the origin of such colors in rocks. It is not the purpose of the present brief paper to deal with the phenomena of colors in rock formations in general nor to review the literature, but it is rather to confine attention to the color phenomena of the well known Vernon red shale of central New York. That the color phenomena in these shales are not merely superficial or due to recent atmospheric action, is proved by the fact that the same features have been found in deep wells passing through the formation.

The Vernon shale has its type locality in the town of Vernon, a few miles west of Clinton, and it extends from southern Herkimer county westward across the State. Wherever exposed the shale presents a striking appearance due to its red color. A section, including the Vernon shales, near Clinton is as follows in descending order:

3 Camillus formation — Dark, thin-bedded shales

2 Vernon formation — (150 feet).
- *c* 5 feet of light green shale
- *b* 135 feet of dull red shale, unstratified and with green spots scattered through the mass
- *a* 10 feet of light green shale

1 Niagara formation — Dark shales and sandy limestones. Contains large concretions.

The red shale, with the green bed at its base, is well shown in the ravine just north of Hamilton College and in Kirkland glen nearly 2 miles southwest of Clinton. The upper green bed, with the Camillus above and the red shale below, are well exposed at the reservoir 2 miles southwest of Clinton. At the "Dug-way," 2

[1] Geol. Soc. Quar. Jour. Lond. 1868. 24:351–400.
[2] Am. Assoc. Adv. Sci. Proc. 1879, p. 311–410.
[3] U. S. Geol. Sur. Bul. 52, especially p. 44–56.
[4] Jour. Geol. 1908, v. 16, especially p. 285–94.

miles south of Clinton, a 2 inch layer of green shale is locally present a few feet above the basal green bed. Scattered throughout the red shale are numerous green spots and after a shower the colors are intensified so that the light green spots stand out in sharp contrast against the dull red matrix. The formation is everywhere highly jointed and soon after exposure to the weather the rock crumbles to a fine dust. The shale is very fine grained and, except for color, it is remarkably uniform from top to bottom. So far as observed it is entirely devoid of stratification planes. Thus it is evident that deposition of the sediment must have occurred in quiet water and under very uniform conditions. Except for certain organic patches below referred to, not a trace of a fossil has been found in the formation near Clinton. At Syracuse the salt bed rests upon the Vernon shale and the absence of fossils from the shale is probably due to the fact that just before the real salt pan conditions the water was too saline to permit much, if any, animal life.

Origin of color in the red shale. The red shale is very fine grained, but examination of the powder or the thin section shows it to be made up chiefly of tiny quartz grains which are imbedded in a red matrix of earthy or claylike material. Occasionally small rhombohedral crystals of some carbonate are noticeable. Because of the opacity and softness of the shale thin sections are difficult to make but it is evident that the color is not inherent in the quartz grains which are themselves very clear and free from color. This is in harmony with Russell's[1] observations on the Newark sandstones, that " their color was not inherent in the particles composing them, but was due to a fine, amorphous, claylike coating which enveloped the grains and filled the intervening spaces."

The red color is unquestionably due to the presence of dehydrated ferric oxid. On treating the red shale with hot hydrochloric acid the red color quickly disappears because the ferric oxid dissolves and from the solution a good precipitate of brown ferric hydrate is obtained by the addition of ammonia. Quantitative tests by Dr A. P. Saunders of Hamilton College showed that a sample of the red shale, treated with hot dilute sulfuric acid, contained 2.25% of ferric iron and .75% of ferrous iron.[2] The amount of ferric

[1] *op. cit.* p. 44.

[2] The amount of ferric iron here given is doubtless greater than is actually present in the oxid form because the acid was boiled until it became concentrated enough to effect a partial decomposition of the green silicate residue below referred to.

oxid is thus very small, but, because of its fine state of division and its diffusion through the mass, it has become very effective as a coloring agent. Barrell[1] discusses this point and believes that where even a very small percentage of the ferric oxid is thoroughly diffused through a rock mass it has great coloring power. It should be stated that after treatment with the hot acid a green insoluble residue is left, whose color disappears after prolonged boiling with concentrated sulfuric acid. Under the microscope this green residue, whose color is doubtless due to the presence of glauconitic material, looks like the ordinary red shale except for color. The final residue is made up chiefly of clear, tiny quartz grains. The relation of the ferric oxid to the glauconite could not certainly be made out but they appear to be very intimately mixed in the earthy matrix surrounding the quartz grains. The origin and significance of the glauconite will be taken up later.

We may now inquire whether or not the red color was present when the shale was deposited. According to Russell's[2] hypothesis, namely "that the sands forming the sandstones of the Newark system and other similar formations received their incrustation of ferric oxid (red) during the subaerial decay of the rock from which they were derived," the red color was present at the time of deposition. Barrell[3] comes to quite the opposite conclusion, especially with reference to red beds associated with salt and gypsum as e. g. in Nova Scotia, the Permian red beds east of the Rockies, etc. Like these red beds, the Vernon shale is also associated with salt and gypsum and was also deposited in rather highly saline water under an arid climate. As Barrell[4] says the lack of the red color at the time of deposition is well borne out by the "usual present development of salt and gypsum in association with gray or yellow sediments." He cites such examples as the Dead sea and the salty flats of the Great Basin of the United States. It is evident that red or reddish brown colors greatly predominate in ancient iron-bearing formations, while the yellow tones, outside of the tropics, are much more characteristic of the modern alluvium.

It is well known, especially as a result of the Challenger[5] dredg-

[1] *op. cit.* p. 289.
[2] *op. cit.* p. 56.
[3] *op. cit.* p. 290.
[4] *op. cit.* p. 290–91.
[5] Challenger Report on Deep Sea Deposits, p. 337 et seq.

ing, that red clay is now forming as a widespread deep sea deposit particularly in the Pacific, but these clays are practically confined to the neighborhood of volcanic regions and they are considered to be due chiefly to the deposition of volcanic dust. Obviously this mode of origin will not apply to the Vernon red shale because it is a terrigenous rather than a deep sea deposit. Some red mud[1] is now depositing locally as in the Yellow sea and along the coast of Brazil, but it is being derived from moist, tropical regions where conditions are favorable for spontaneous dehydration of the ferric oxid. Such dehydration of ferric oxid under conditions of warmth and moisture is well known to account for the deep red color of laterite, the soil so characteristic of the tropics, and which colors the river silts. The climatic evidence is opposed to such an origin of color in the Vernon red shale.

Applying Barrell's view, the iron in the Vernon shale was present at the time of deposition in the peroxid form, but hydrated and therefore not red, and the dehydration with resulting red color was largely due to great pressure and moderate temperature in the consolidated and deeply buried sediment, since hydrated ferric oxid readily gives up its water under such conditions. This dehydration, combined with the finely divided and diffused ferric oxid, the writer believes accounts for the red color of the Vernon shale.

Very commonly stains of yellowish to yellowish brown oxid of iron may be seen along fractures in both the red and green shales, and these are clearly due to the hydration of some of the ferric oxid since exposure to the weather.

Origin of the green spots. As already stated one of the striking features of the Vernon formation is the presence of numerous light green spots scattered through the dull red shales. So far as tested the material of these green spots is precisely the same as that in the green shale beds in the formation. The spots range in size from a fraction of an inch to several inches in diameter. They are mostly spheriodal to flattened spheriodal and seldom irregular. When flattened the long axes lie horizontal thus suggesting that the flattening has been due to the pressure of overlying strata and this since the spots were formed. The green spots are nearly always in sharp contact with the surrounding red shale but,

[1] "Mud is a mixture of minerals in a state of extremely fine mechanical subdivision, but not chemically decomposed, thus differing from clay." Scott's Geology, 1907 edition, p. 267. The Vernon shale is essentially a hardened mud.

aside from color, there appears to be no difference in character between the red and green materials. Although the spots are very irregularly arranged they are, nevertheless, pretty uniformly distributed through the whole mass of red shale, and it is estimated that they make up less than 2% of the mass. Another fact of importance is the frequent presence of dark to black centers in the green spots. Such dark centers which are particularly well shown in Kirkland glen, range in diameter up to a half inch and they are rarely concentric. A much lighter shade commonly extends from the black center well out toward the periphery of the green spots. These dark centers are certainly organic, the dark color being completely removed by heating before the blowpipe.

After treating the green spot material with hot hydrochloric acid a green glauconitic residue is left precisely like that from the red shale. Ferrous iron has gone into solution as shown by the heavy blue precipitate with potassium ferricyanide. Ammonia, however, fails to give the brown precipitate for ferric iron, while sulphocyanate gives only a slight coloration. This coloration is doubtless due to the fact that by infiltration a small amount of hydrated ferric oxid has comparatively recently been mixed with the green spots. Ferric oxid is, therefore, practically absent from the green spots. According to an analysis made by Dr A. P. Saunders, a sample of the green spot material contained 1.19% of ferrous iron obtained from the dilute sulfuric acid solution. The writer believes that the ferrous iron is largely present in the carbonate form. Both the red and green shale when treated with cold hydrochloric acid show almost no sign of chemical action but after warming a vigorous effervescence sets up and this suggests iron carbonate. This carbonate doubtless forms the rhombohedral crystals seen in thin section.

Many years ago Vanuxem[1] described these green spots and stated that: "It is not easy to resist the impression that the green color is the result of a change in the red particles, the peroxid of iron being reduced to a protoxid." He makes no mention of the black organic centers. His view is still commonly held but there are certain objections to it as for example the highly improbable assumption that the red color was original and the fact that the chief coloring matter in the green shale is glauconitic and not protoxid of iron.

[1] Geol. 3d Dist. N. Y. 1842. p. 97.

Maw,[1] in referring to green spots in general, stated that: "The generally accepted theory, and that suggested by De la Beche in explanation of the phenomenon, is, that the discoloration has been brought about by the reduction of the sesquioxid to a lower state of oxidation of less coloring power by simple chemical reaction with the fossil carbon." The objections above given apply in this case also but the influence of the organic matter is here clearly brought out. As early as 1831 Fleming[2] recognized the agency of decomposing organic matter in the production of the light colored (but not green) spots in the Old Red Sandstone.

It is well established that decomposing organic matter will effect the reduction of ferric to ferrous iron and the organic matter in the green spots of the Vernon shale has no doubt caused such a change, but since, in this case, the ferric oxid was in the hydrated state and hence not red, it is not correct to say that there was a change in color from red to green. Rather the writer believes that the presence of the organic matter has simply prevented the appearance of the red color in the immediate vicinity because the oxid of iron has here all been reduced to the ferrous condition. Within the spots, then, the green color of the glauconite is allowed to come out, and it is this rather than the small percentage of iron in the ferrous condition which gives the green color. In each case the size of the green spot has been directly dependent upon the amount of the decomposing organic matter. The presence of ferrous iron in both the red and green shales may be readily explained because this iron is probably mostly in the carbonate form which would be pretty freely disseminated through the whole shale mass.

Origin of color in the green shale. In view of the above statements the explanation of the origin of the color in the green shales, at the base and the summit of the red shale, becómes a comparatively simple matter. The character of the material in the green shale is, in every way, like that in the green spots and the explanation of the origin of the color in the spots may be applied here also. In this case, however, the organic matter was probably more abundant or, at least, it was more finely divided and scattered through the mass so that all of the ferric

[1] *op. cit.* p. 371.

[2] "Old Red Sandstone" by Hugh Miller, quoted on p. 235.

oxid in the green beds has been reduced and there the green glauconitic color appears throughout. In the same way the color of the green streak in the red shale, above noted, has been produced.

Regarding the origin of the glauconite in the Vernon shale the writer ventures to suggest that the conditions for its formation were very favorable such as the deposition of the fine ferruginous sediments very slowly and uniformly at the so called "mud line," in the presence of decomposing organic matter. Since the waters were rather highly saline and since no trace of fossil shells has been found, it is conjectured that the organisms were plants of the seaweed type. It is well known, especially by the studies of the Challenger[1] expedition, that greenish glauconite muds are now forming in the presence of decomposing organic matter over considerable portions of the ocean bottom particularly near the borders of the continental shelves. In the case of the Vernon shale there was an excess of ferric oxid over that necessary to the formation of the glauconite and the dehydration of this excess oxid, as above explained, has given rise to the red color of the shale.

In Kirkland glen an interesting example of the effect of modern decomposing organic matter has been observed by the writer. Along a joint plane for 6 or 8 feet the ferric oxid has been reduced so that, for an inch either side of the joint plane, the shale is green. This is thought to be a purely superficial effect since the hillside is heavily covered with humus and surface waters charged with humic acids have traveled along the joint plane thus causing a reduction of the ferric oxid so that the green glauconitic color is brought out.

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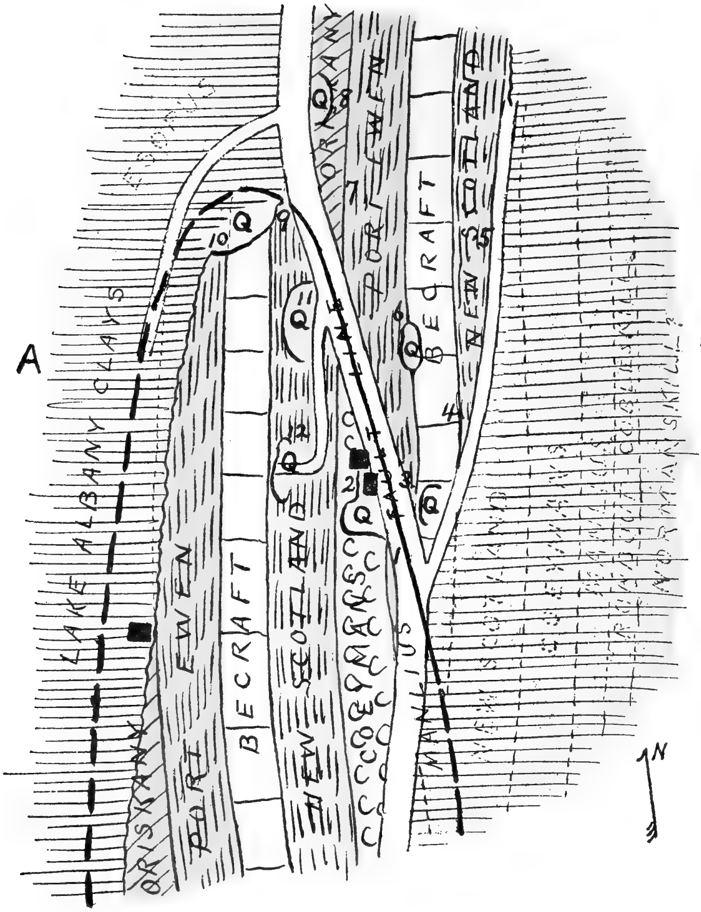
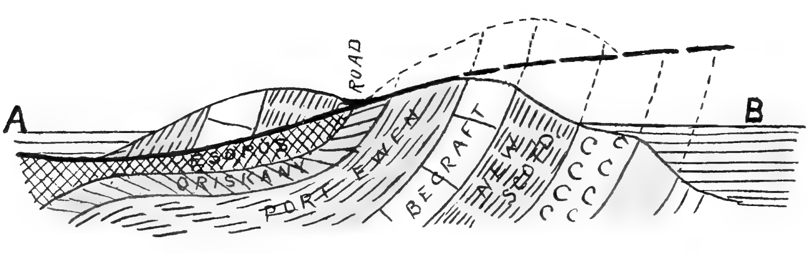
[1] *op. cit.* p. 385–91.

Plate 1



Sketch map at stone crusher, Canoe hill, Saugerties, N. Y.



Section along A-B of above map, showing structure and derivation of the fault block

DOWNWARD OVERTHRUST FAULT AT SAUGERTIES, N. Y.

BY GEORGE H. CHADWICK

Canoe hill, north of Saugerties village, Ulster co., is represented on the Catskill topographic sheet as a dumb-bell ridge with the highway passing obliquely across the narrowed middle. It is surrounded by clay plains of Lake Albany age, along which, on the west and north of the hill, runs the West Shore Railway. The Canoe ridge is a part of the range of Helderberg limestone hills, known locally as the Kalkberg (pronounced collabarrack,—"Collar Back" of the map!), which here sags under the Albany clays, its summits rising as a chain of islands out of the plain.

During a recent visit to this hill in company with the two gentlemen named beyond, the writer was impressed by the occurrence here of an overthrust almost identical with those in the Vlightberg at Rondout [*see* van Ingen & Clark. Disturbed Fossiliferous Rocks in the Vicinity of Rondout, N. Y. N. Y. State Mus. Bul. 69]. Although it seems likely that this fault has been observed by others, no reference to it now occurs to the writer, and a brief account, with diagrams, is therefore presented because of the conspicuous nature of the faulting and the more ready accessibility of the locality as compared with the Rondout faults.

The locality is in the first hill northeast of Saugerties depot, and not over a mile distant. The map [pl. 1] shows the road crossing the hill in the oblique valley determined by the fault. The village stone crusher, located at the corporation line, furnishes a conspicuous landmark for the visitor. Opposite this, on the east, a blind road leads under the hill. Various quarries and diggings [Q] add to the ease of study of the ledges which are everywhere conspicuous.

The rock at 1, by the roadside as one turns into the crusher quarry, is much brecciated and shot through with calcite seams. It looks like upper Manlius, but no fossils were found. The brecciation is probably due to its lying in the fault zone. At 2, the cliff face behind the stone crusher, the limestone is hard, blue and vertical, with calcite veins and geodes. The fossils are Sieberella galeata, Favosites etc., of the Coeymans limestone. Passing across the highway to 3, where the Manlius would

naturally be expected, the rock is found to be a bluish impure calcarenite with Leptaena rhomboidalis, unlike the Coeymans and not so steeply inclined. This grades rapidly downward (easterly) into a coarsely crystalline "coquina" rock, carrying Spirifer cyclopterus, with greenish shale partings in the lower portion (at locality 4)—unquestionably the Becraft limestone. Mr Cole reports Spirifer macropleura abundant in the shaly limestone below this, along the road at 5 and beyond, indicating the New Scotland. The rock at 3 is therefore the lower Port Ewen, with which it fully accords. The basal bed of this, close down upon the Becraft, carries some chert nodules, as at Catskill.

The Becraft and Port Ewen have an almost unbroken outcrop northward along the ridge. A digging at 6 shows plenty of Aspidocrinus in the upper Becraft, and a gradual change of rock texture at the contact with the Port Ewen. The higher layers of the latter begin to appear, and are decidedly shaly and with oblique schistosity, as at Rondout. They occasion a slight depression and are not well exposed. Beyond them again are harder layers, somewhat cherty, at 7, forming a slight ridge; they carry Leptocoelia flabellites abundantly, also Spirifer cyclopterus and are either the highest Port Ewen (beds 22 to 26 at Rondout) or lowest Oriskany. In appearance they resemble the Hudson valley "Schoharie grit." The dip is steep and the surface of the highest layer has been largely uncovered in a road-metal digging at 8. Here only the talus is being removed and the rock face is untouched but bared. It is horizontally glaciated, and a striking feature of the polished surface is the occurrence of Taonurus cauda-galli as lighter colored spiral patches resembling paint blotches. Polished chert nodules also appear prominently. Slightly exfoliated surfaces show the normal burrow structure of Taonurus, side by side with Spirifer murchisoni and Leptocoelia. This is therefore undoubted Glenerie Oriskanian and indicates a rapid loss in calcareous content in the few miles between Glenerie and here.

Standing in this pit, one looks against the north end of the other (or fault-block) ridge, with its nearly vertical beds well shown in an old quarry cutting. The nearest rock, at 9, is New Scotland shale with beautiful and frail silicified fossils, such as are found in it at High Falls station on the Kingston &

Ellenville (O. & W.) Railway. These are wholly different in appearance from the silicified shells of the Oriskany, Port Ewen or Kalkberg limestones and are readily distinguished. They come from essentially shaly layers, are very delicate, neither thickened, coarsened nor iron-stained but often semitranslucent blue with the finest edges and markings sharply preserved. The transition to the Becraft and thence to the Port Ewen is completely revealed, with excellent collecting opportunities. At 10, the west side of the same quarry, it appears impossible to draw the Becraft-Port Ewen contact at a bedding-plane. The two rocks are perfectly continuous, only the change of fossils and the appearance of chert nodules marking the inception of the Port Ewen. This is unusual; a distinct bedding-plane separates them at Rondout, Alsen and Catskill.

From 10 a red barn is seen to the south, under the west base of the hill. Mr Cole states that beds with many Homalonotus vanuxemi, supposedly Oriskany or perhaps upper Port Ewen, occur from this barn southward, having a low westerly dip.

Returning along the highway, another big cutting at 11 shows the same fossiliferous New Scotland shales as at 9, and these beds are being excavated again at 12, here quite vertical to beyond vertical at the top. No attempt has been made to discriminate the Kalkberg limestone in the field or on the map, from the underlying Coeymans.

The offset between the two halves of the hill is plainly evident. Only the narrow highway separates outcrops as discordant as Oriskany and New Scotland, or Port Ewen and Coeymans, and this highway is seen to lie in an oblique hollow across the hill having every earmark of a fault valley. Standing on the north of the road, say at 6, the fault plane is felt to be the hill slope on which one stands, dipping at a low angle to the westward and a steeper angle to the southward. The fault block is like the decapitated crest of this hill, slid westward and slightly downward for the space of two or three hundred feet upon the yielding surface of the Esopus shale (which makes the next ridge to the west beyond the railway), just as at Rondout. Of course, as a matter of fact, the slip took place under much overlying rock and the present forms are erosional. The movement was a true overthrust, not a landslide. One is tempted to inquire whether this is not a piece of the identical fault

which appears at Rondout, and whether it is not also one with the similar horizontal overthrust described by Davis at Austin's millroad near Catskill [Folded Helderberg Limestones. Mus. Comp. Zool. Bul. v. 7, No. 10, fig. 3 and p. 324], with like puzzling features (not yet worked out) in the Kalkberg at Alsen and Cementon, and finally with the great fault near Schodack Landing and southward along the Appalachian front into Georgia. The influence of such a plane, nearly horizontal but rising and falling in great gentle undulations, would affect a wide area (compare the Rome folio, in Georgia) and produce seemingly very irregular, disconnected and puzzling results, especially where it hades, as in this case and so often, considerably beyond the horizontal.

If not one and the same plane, these instances must at least appertain to the same set of movements, the same "rift," extending along the entire eastern edge of the folded Appalachians as a constant and normal feature. The recognition of this for our miniature Appalachian hills of the Hudson valley will assist the field worker materially and will rapidly multiply the known occurrences of this structure.

The writer owes the opportunity for these observations to the Rev. Thomas Cole, Episcopal rector at Saugerties and an acute observer of local geology, in company of whom and of Prof. J. W. Eggleston of Harvard the reconnaissance was made.

JOINT CAVES OF VALCOUR ISLAND — THEIR AGE AND THEIR ORIGIN

BY GEORGE H. HUDSON

Wherever the shore of Valcour island consists of the purer dolomite limestones of the middle Chazy beds, it has been penetrated, sometimes to considerable depths, by a number of small caves which owe their origin in great part to the solvent power of water. The majority of these caves seem to have had their beginnings in exposed joint or fissure planes, and as a rule they have closely followed them in their subsequent development. Such deviation as exists is expressive of a well marked tendency to develop vertically. The form is usually somewhat wedge-shaped with the apex of the wedge uppermost, and in the smallest caves this edge may sometimes be seen to be working upward across a dipping bed without any apparent fissure or joint plane as a guide. If the small cave has penetrated to considerable depths the inrushing volume of water from a wave condenses the cave air and this in turn shoots out a smaller volume of water at the cave top with great velocity. These spouting caves lose the sharp upper edge of the wedge and develop arched tops. The roofs of those caves which rise still higher and reach or pass the present high water mark of the lake, lose also their wedge form and develop wide arches or even flat roofed tops. In the latter instances it is apparent that cave-widening agencies have become more effective than those bringing about upward extension. A few caves have been developed upwards far enough to reach the cliff top. Among these are to be found a still smaller number that have had a portion of the roof fall in some distance back from the shore line. These therefore present us with small sink holes and natural bridges. Where these caves occur they develop in rather close proximity to each other, so one has to go but a few rods to pass many small mouths.

The general external appearance of these caves where well developed, may be seen in plate 1 — a view of a portion of the north shore of Paradise bay on the east side of the island. The wedgelike form and close proximity of the caves are both well shown. The cave near the middle of this view has a sink hole some distance back and a natural bridge between it and the sea wall. A view of this small sink hole is shown in plate 2. The sea wall here faces southeast by south and is only subjected to strong wave action during

southerly gales. A breaking wave rarely throws spray as high as the top of the cliff. Where the lake bottom, just off the foot of the cliff, can be seen at low water, it is found to consist mainly of bare bed rock. Pebbles as abrading tools can rarely be used against this wall and the water here never picks up enough sediment to become in the least discolored.

Plate 3 presents a view of a portion of a cliff about a mile distant from that shown in plate 1 and on the opposite or west side of the island. Here the wall faces west by south. A few of the caves developed on easterly running joints have somewhat the appearance of bedding or pebble-eroded caverns. It may easily be seen that the influence of the bedding in their formation was slight, for the lower portion of the cliff does not differ enough from the upper in character to make it a very effective factor. Neither can we very seriously entertain the idea that they were pebble-cut, for the water near their mouths is now too deep to allow waves the use of any visible abrading materials. Waves can break against these cliffs only during westerly winds. The nearness of the mainland prevents a very heavy sea and westerly winds in this region are of short duration. A little to the left of the region here shown the cliff face turns easterly and there, on southerly running joints we find the typical wedge-shaped forms like those shown in plate 1. A little to the left of the center of plate 3 is a cave opening that reaches nearly to the top of the cliff, the cave here developing on a southerly running joint or fissure. This cave has maintained much of its wedgelike character and the influence of neither weaker bedding nor pebble-cutting is at all apparent in the outlines of its mouth. In their earlier stages all of these caves were no doubt developed through the same agencies. A very large part of the present difference between the caves shown in plate 1 and those shown in plate 3 may be due to the effects of glaciation acting on the latter. We may note that southerly facing cliffs would be in a measure protected from strong glacial action while westerly facing cliffs would receive no protection from a planing action which would cut across their cave mouths. The form of the most distant large cavern on plate 3, the shape of the cliff face just south of it, and the stranded boulder removed from this wall, all suggest glaciation as a modifying agent. Additional evidence to this effect will be presented.

Near the cliff shown in plate 1 is a small island called Spoon island which is separated from Valcour island by a narrow glaciated channel. A portion of its west wall as it appeared October 2, 1909,

Plate 1

Cliff in Paradise bay (on east side of Valcour island) facing southeast by south. The cave near the middle is open at the top near the face of the cliff and has a sink hole some distance back with a small natural bridge between. From a photograph taken in 1902

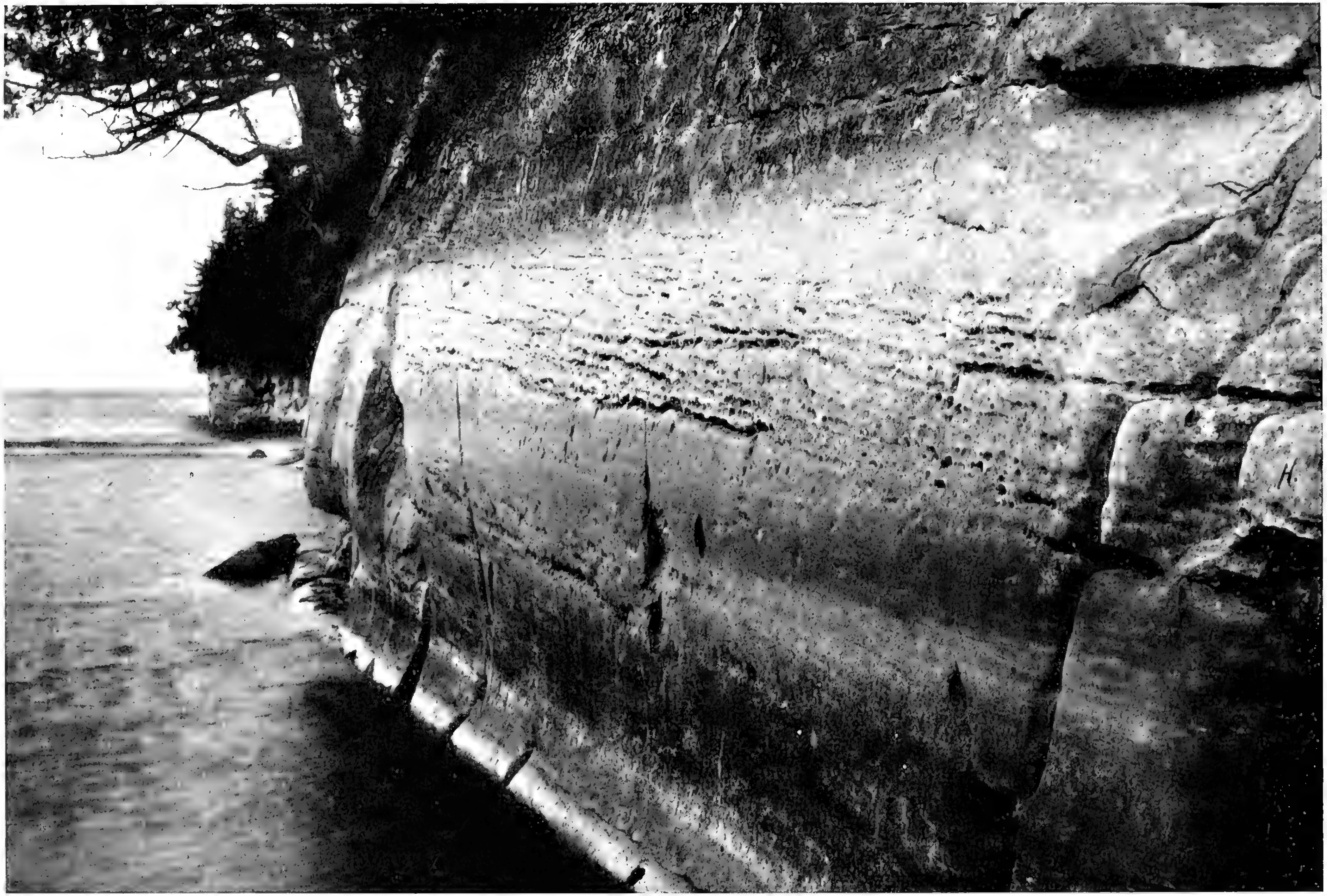
Plate 2

View of a small sink hole some distance back from the cliff face shown in plate 1. There are indications here that this opening was due to the crushing in of the cave roof by the pressure of glacial ice. The small light spots in the lower left part of this opening are portions of the distant cave mouth. From a photograph taken November 2, 1909

Plate 3

View of a portion of a cliff on the west side of Valcour island near the lighthouse. From a photograph taken October 9, 1909. The cliff here faces west by south.

Plate 4



A portion of the west wall of Spoon island from a photograph taken October 2, 1909. The cliff here presents an undoubtedly glaciated surface which retains, apparently, the younger and inner ends of caves whose older and outer portions were carried away during the movement of the Wisconsin ice sheet.

is shown in plate 4. This wall still retains for the greater part its former glaciated surface. The whitish horizontal band, due to the dried remains of a sheet of green algae which covered this portion of the wall in the spring, is an indication of the water level at that time. It may be noted that the portion of this wall covered by water the greater part of the year is better preserved than either the portion only covered in spring or the portion above this which is now never covered. The water surface shown in this plate cuts across the mouths of several small wedge-shaped caves or cavelets and their appearance is very suggestive of glaciation after their formation. The clean and sharp junction with the smooth curved glaciated wall makes them appear like the younger ends or remnants of older and larger joint caves. The fact that a very marked and glaciated notch has been cut out from the under portion of the cliff just north of them and at their level, may be taken as indicating that a few closely packed joint caves had here so weakened the cliff as to allow glacial action to carry them in part away. Their former presence is shown by their bases which still exist. The well preserved character of this portion of the wall is due to the proximity of Valcour island on the west, to a bar at the north (here indicated by the faint lines of surf), and to the fact that waves from the south are broken by cliffs as they enter the channel.

There are a few instances in which these caves have followed bedding planes, and cut such wide and deeply penetrating caverns as to bring down great masses of the rock above. Plate 10 represents a portion of the shore of Valcour island as seen from the south end of Spoon island October 23, 1909. The great fall of rock at the left end of the cliff is due to the collapse of such a cavern. A little to the right of the middle of this view there arises from under the water a second low but wide cavern which follows the bedding plane seen at the right. The vertical dimensions of this cavern become rapidly less as we move up along the bedding plane and they become practically zero before we reach the highest part of the dried algae belt, plainly seen as a whitish band parallel with the water surface. The width is considerably greater than here shown because it extends to the left under water. The distance to which it penetrates the cliff horizontally was greater than could be determined. The wall here is a north and south fault scarp, is on the upthrow side and is but a few meters from the fault line itself. Not far back of this we find a few parallel faults with very small vertical displacement, but revealing, by slickensided surfaces, a larger horizontal component. The cliff to the right of the portion

here shown presents some nearly horizontal joints which curve up southerly and cross the beds. The block here has been subjected both to a strong uplift and to a thrust toward the south. The indications of vertical and lateral displacement make it quite possible that these aberrant caverns are also following some preexisting planes of fracture, and that they are in their origin not essentially different from the caves first mentioned. The other cave mouths which show on this plate illustrate clearly the tendency to acquire verticality.

Now numerous as these joint caves are, they are found with a single exception where the present water line of Lake Champlain either just keeps them covered or cuts across their mouths during some portion of each year. The high water level of spring leaves but comparatively few of them uncovered, but the number brought into view rapidly increases with the lowering of the water level. In other words, the floors of all but a very small number of these caves lie a meter or more below the present low water level of the lake while their roofs stand at varying hights above this level, some of them reaching far above that of present spring floods. Their horizontal depth is not so easily measured but many small mouths give forth deep bass notes when any sea is running and their booming may be heard for considerable distances. A few can be followed into the cliff for several meters but a narrower portion may be always seen to penetrate to still greater depths. Plate 5 shows a sink hole many meters from the shore line and the sink hole shown in plate 6 is 150 meters from the nearest lake margin.[1]

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[1] The sink holes shown in plates 5 and 6 both seem to be of comparatively recent origin. In plate 5 a border of fresh earth, on which nothing was growing, is to be seen around the front of this opening. This feature and the overhanging sod at the left are indications of the removal of much earth in a single season. If anything like an equal amount has been washed out each season the sink hole can not be many years old. That it was covered in comparatively recent times is also shown by the presence of portions of old stumps and roots on the rock surface of the more distant border of the pit. It does not seem likely that we are here dealing with a recently fallen rock roof but it does seem likely that such a roof was crushed in during the last stages of the ice sheet and that the opening was then filled with till and afterward covered by Pleistocene deposits. As soon as the present land had lowered sufficiently to allow waves to run in and out of the cluster of narrow caves here seen to connect this pit with the lake, the water would undermine and carry away these deposits and so allow the surface to finally cave in. Such a conclusion would make the caves connecting this pit with the lake, preglacial.

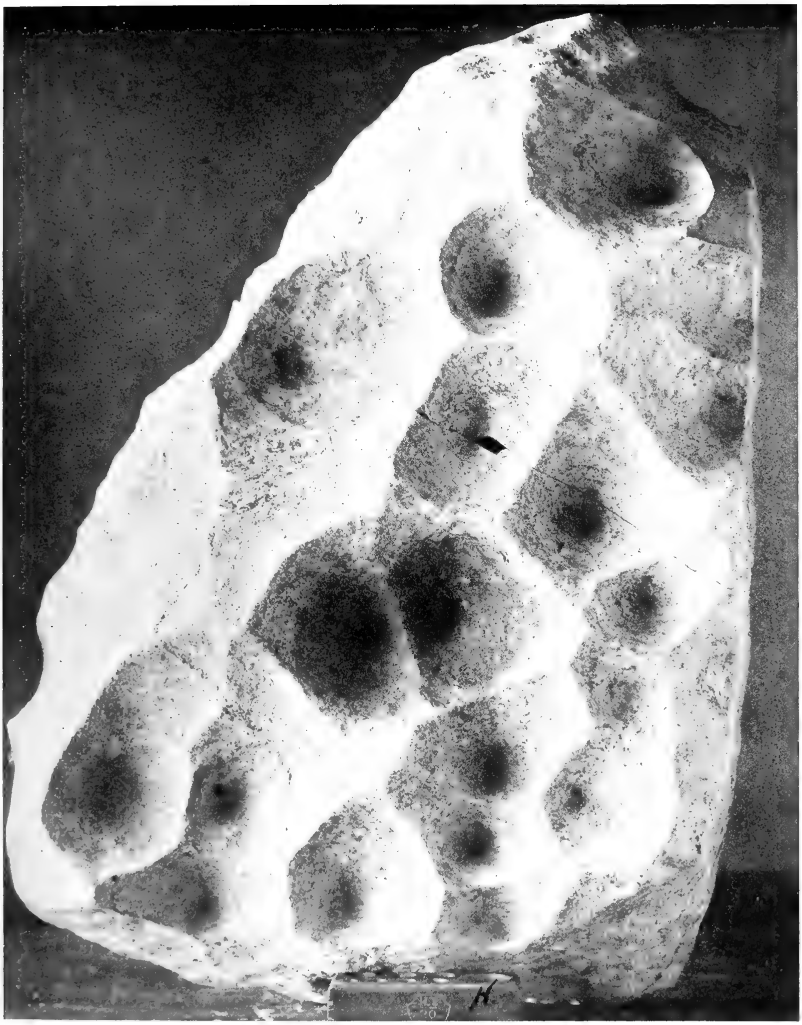
Plate 5

View of a sink hole on the west side of Valcour island, a short distance south of the old steamboat dock. The person in the hole is holding up a meter stick vertically, the arrows marking the ends of the stick. From a photograph taken October 16, 1909

Plate 6

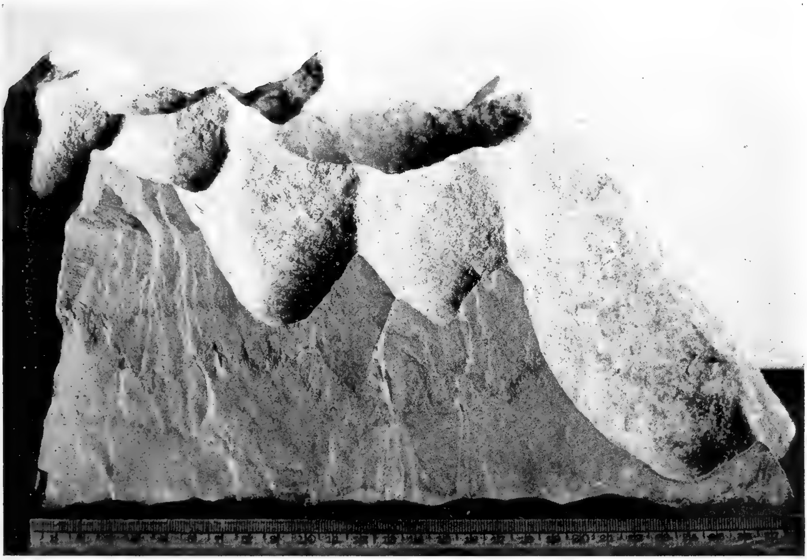
Sink hole on the lower terrace (meadow) of the north farm and 150 meters from the west shore of Valcour island. From a photograph looking north by west and taken October 10, 1909

Plate 7



Block of pure dolomitic limestone, of Lowville? age, cut by confluent cupholes. Vertical distance from table surface to upper point of block 463 millimeters. Specimen now in the New York State Museum

Plate 8



View of fractured end of the lower portion of the block shown in plate 7. Presents a side view of the cupholes and forms of figures produced by nearly vertical sections of the same. Shows also the edge of the dent-pitted surface below, and indicates approximately the comparative value of the two forms of erosion as geological agents

The very marked relation of these caves to the present water levels of Lake Champlain strongly suggests this lake as their cause. On the other hand, the vertical depth to which they descend below low water, their increasing number at the lower levels, their great width and horizontal depth, their appearance on fresh glaciated surfaces and their apparent modification by glacial action, all strongly suggest a preglacial origin for them and leave them as rock inscriptions commemorative of lake Valcour.[1]

During the past season these caves have been studied with the hope of finding evidence which shall serve in determining their age and the manner of their origin. It is the purpose of this paper to present the evidence found. The first of this evidence deals with a peculiar feature of erosion found on all cave surfaces which have been acted upon by the present lake waters. It will be necessary to treat this feature somewhat in detail and this we propose to do under the subtitle which follows.

Dentpits. The beds of the uppermost Chazy are in part covered where they crop out at the northeast corner of the island, but under the water of the lake and some distance out from the shore line, wave action has swept them comparatively clean. During the period of phenomenally low water in 1908 a series of samples of these beds, which run from just below the sandstone capping of the Chazy to the beds of the Black River epoch, were secured. One bed of very pure dolomitic limestone of Lowville age (?) was deeply cut on its upper surface by confluent cupholes[2] whose edges were so sharp that it was an exceedingly painful matter to stand on them barefooted even though the water was more than a meter deep. This bed had been undercut, and a large block had fallen from its edge and now lay in a number of smaller pieces. These pieces however still remained in their proper relations to the bed and to each other and none of them had been turned over by wave action. On raising a piece of this bed weighing a little over 46

The sink hole shown in plate 6 is in a meadow on the lower terrace of the north farm and seems to be a still more recent opening. This hole had been partially filled up with some old cedar stumps, and three upright poles served to indicate its position to any one mowing the field. These stumps and one of the poles were temporarily removed in order to obtain a view of the rock edges in the opening. This opening was not sufficiently illuminated to allow its interior to show any detail in the photograph.

[1] *See* Some Items Concerning a New and an Old Coast Line of Lake Champlain. N. Y. State Mus. Bul. 133, p. 159–63.

[2] *loc. cit.* p. 160–61, pl. 1–5 inc.

pounds, my attention was called to the very peculiar and clearly cut pattern on its under surface. As this block must be considered in evidence, it is represented here on plate 7 to show its upper surface, plate 8 to show a section through upper and under surfaces, and plate 9 to show the under surface.

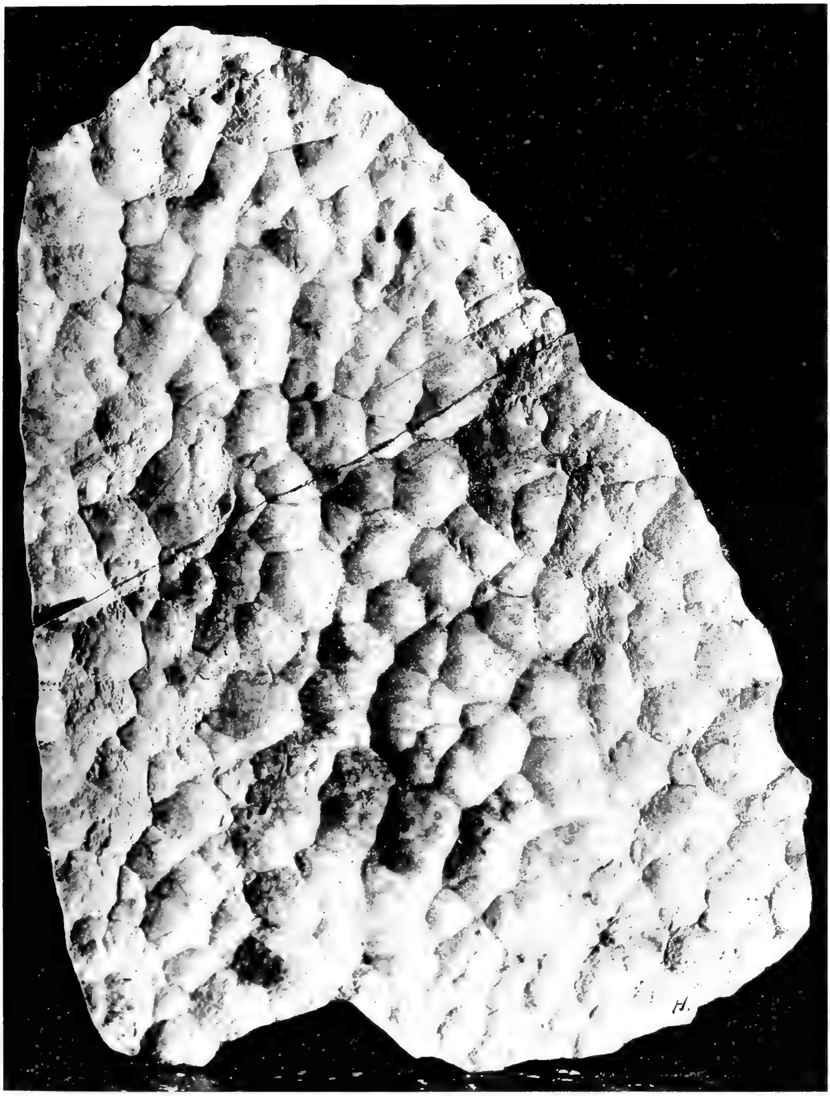
During the early summer of 1909 an examination was made of the cave whose arched mouth, rising just above the whitish dried algae band, may be seen a little to the left of the center of plate 10. Here a peculiar erosion pattern similar to that on the under side of the limestone block referred to [pl. 9] was discovered but with this difference: on the limestone block the surface was of small area and all the dentlike depressions were confluent; here the pattern was spread over many square meters of surface and varied in its degree of complexity all the way from the separate circular depressions near the mouth of the cave to the horizontally alined and crowded pattern of the deeper recesses.

Plate 11 is from a photograph of a portion of the north wall of this cave taken August 1909. The depressions are least crowded in the upper right-hand portion of the plate or in that portion of the cave nearest the mouth and under water action for the lesser portion of each year. A distinct horizontal arrangement of these depressions is to be noted, and we are compelled to attribute it to the direction of the flow of water in and out of the cave during wave action, and not to bedding planes. For convenience in reference we shall call this cave *Bat cave*.

On visiting the recesses of the cavern with a fallen roof, near the left end of the cliff shown in plate 10, a still more remarkable arrangement of these depressions was discovered. Plate 12 is from a photograph taken October 2, 1909. We are here looking westerly across a higher portion of the inclined cave floor, and the lines taken by the confluent depressions are clearly seen to take the natural lines of water discharge. Even in the vertical fissure shown here the lines are not horizontal and neither would be the direction of the outpouring water as a wave receded.

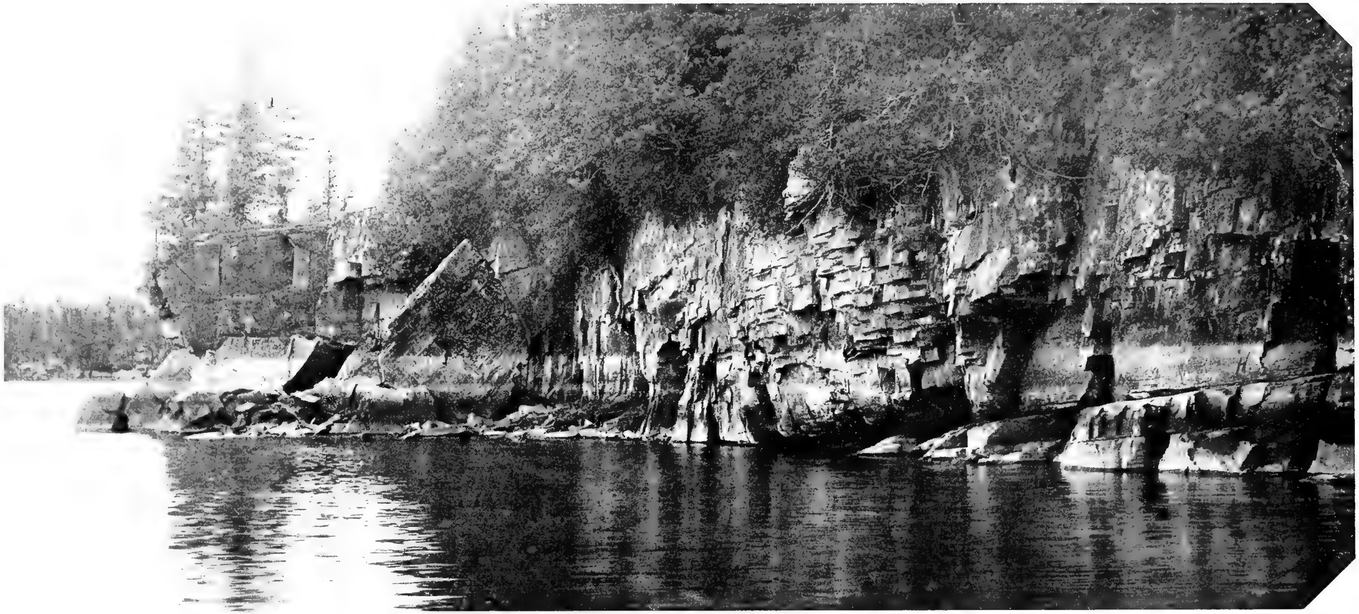
Plate 13 is a view which penetrates deeper into the cavern than did plate 12. The vertical fissure at the left of plate 12 is seen at the extreme right of plate 13. In this last plate the relation of these lines of confluent depressions to the direction of water flow is still more striking. An examination of these two plates will also reveal the fact that the sharpest lines of intersections lie deepest within the cave recesses where they are protected from other

Plate 9



The undersurface of the block shown in plates 7 and 8. Note difference in character of marginal and central dent pits. The former seem to show the results of differential solution due to acids generated by microorganisms. Figure must not have botryoidal appearance.

Plate 10



The south end of the west wall of the channel between Spoon and Valcour islands. From a photograph taken October 23, 1909

Plate 11

View of a portion of the nearly vertical north wall of Bat cave. The surface is covered with confluent dent pits. Their intersections are sharp and these raised edges show no wear from movement of material on the cave floor. The photograph was taken August 1909 and just after the removal of blocks from under the horizontal line *a-a*. The downward slant of these lines toward the right is due to the high position of the camera.

Plate 12

Wave-worn recesses of the bedding plane cavern with the fallen roof. From a photograph taken October 2, 1909. Note the runnels on the inclined floor. They are formed of confluent dent pits and converge toward the place of discharge at the left. Note also the alinement of the dent pits on the left vertical wall of the open joint in foreground.

Plate 13

Wave-worn recesses of the cavern shown in part in plate 12. From a photograph taken October 23, 1909. The vertical open joint at the extreme right is the same as was seen in the middle distance of plate 12. This view, taken through a narrow opening between the rock masses in the foreground (out of focus), looks along and up the lines of flow — not across them as in plate 12. Foreshortening has exaggerated the apparent dip of this surface. See foreground of plate 12 for a truer presentation of the amount of inclination. That these channels are formed of clean-cut confluent dent pits is clearly seen. Note them also on other wall of vertical open joint.

erosive agencies. This feature of erosion is both peculiar and important enough to receive a distinct name, and the name *dentpit* is hereby proposed.

Dentpits defined. Dentpits are vortex-formed, shallow rock concavities whose width greatly exceeds their depth and whose axes are perpendicular to the rock surface. Their diameters are usually between 1 and 5 centimeters, and a separate dentpit has much the same form and smooth character as the concave surface of a watch crystal. Sections along their axes give curves that are approximately arcs of circles whose radii are usually between 3 and 4 centimeters in length. These dentpits when confluent often present an appearance much like that of hammered brass, but their intersections are usually very sharp and clearly defined. Like cupholes they are sometimes seen to be arranged in definite lines which take the direction of the water flow.

The differences between dentpits and cupholes are both numerous and well marked. Cupholes present hyperbolic or parabolic outlines on longitudinal sections. The former are usually between 5 and 15 centimeters in diameter and their depth is usually greater than their width; their axes are always vertical even though cut on the sides of steeply sloping surfaces, and they are cut or deepened directly downward; they usually contain some fine silt in their deepest portions. Dentpits, on the contrary, present circular outlines on perpendicular sections. They are usually between 1 and 5 centimeters in diameter and their depth is very markedly less than their width; their axes are confined to no one direction and their cups may be deepened even directly upward; no silt ever remains in their depressions. Dentpits are developed on rather pure calcareous rocks where the water is strongly agitated by frequently broken and reflected wave motion and where the water carries but little matter in mechanical suspension.

Formation of dentpits. When quiet pure water rests against limestone, molecules and ions of the latter become detached and pass into the water; this process we call solution. The presence of such molecules and ions in the film of water next the rock interferes with further detachments, an equilibrium is soon attained and solution ceases; the water is said to be saturated. If the water has a rapid molar motion it will produce a more rapid solution of the limestone because it never allows the film next the limestone to become saturated, or continually removes it after saturation. The more rapid the movement of the water the more rapid the solution,

provided that the water forced in to take the place of that whirled away is itself unsaturated, and also provided that there is no limit to the speed with which such molecules may become detached when in actual contact with unsaturated films.

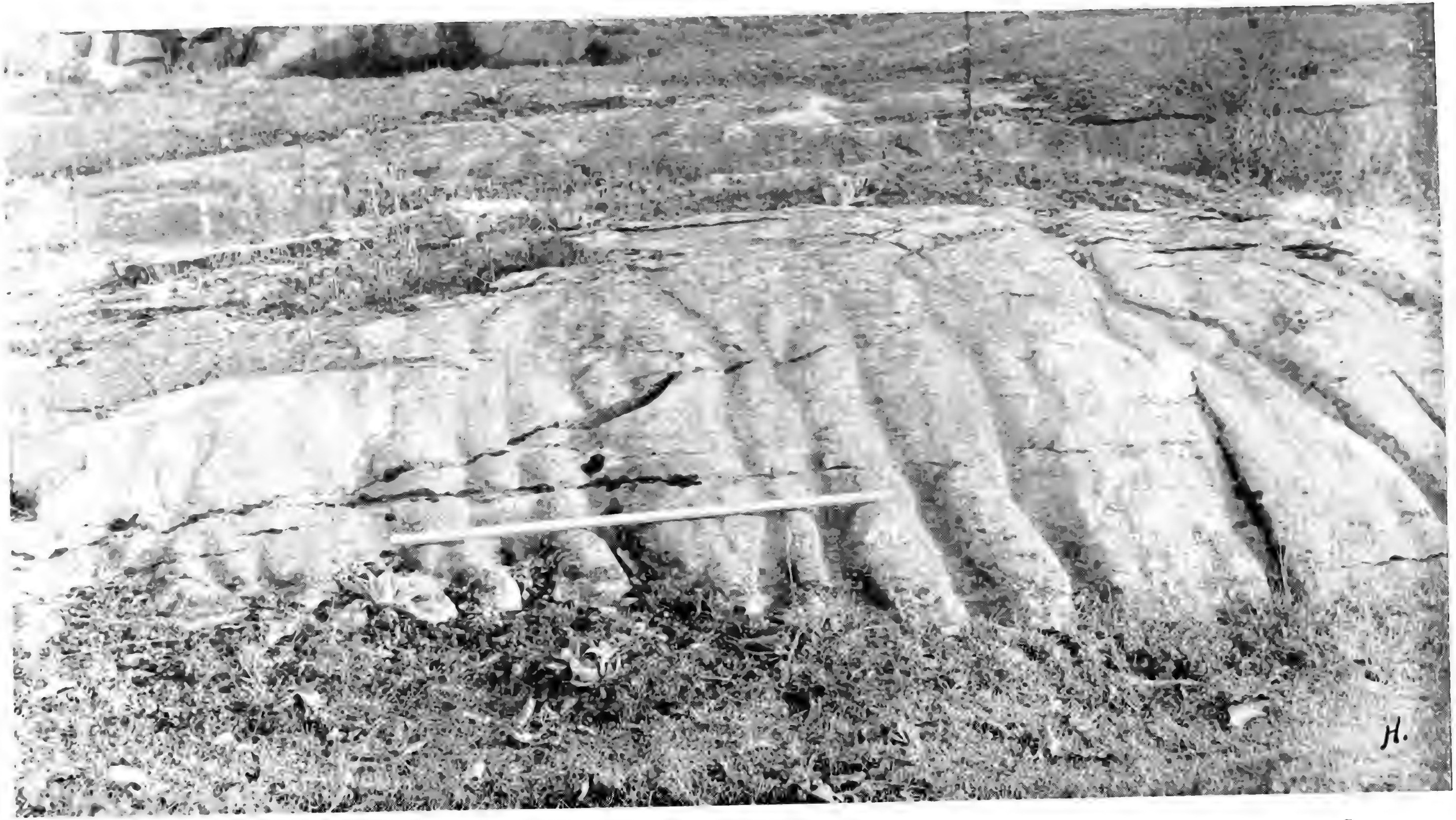
In true differential solution we are confronted by a surface whose relief speaks of different degrees of solubility due to differences in chemical or other character of the surface in question. Our recent discussion however should make it clearly manifest that we may have a relief that speaks clearly of differences in motion (speed and direction) of the solvent and dentpits present us with a relief perhaps in great measure so formed.

That a solid rock relief may express this difference in speed and direction and motion of a solvent is also shown by numerous limestone sheepbacks of this region, which exhibit deeply cut rill channels on their exposed surfaces. A typical boss of this character is shown in plate 14. The channels may be seen to start from near the top of a well rounded boss, where they have no appreciable depth, take the natural direction of water flowing down the inclines and sink to a depth of 15 centimeters below the surface before the rill becomes 150 centimeters long. This is a rate of increase of 1 in depth for every 10 linear. These channels are usually subparallel and are often but 20 to 30 centimeters from each other. The only abrading materials which are here to be obtained are atmospheric dust and such particles as are separated from the rock through solution. These rill channels are not wholly due to rainfall but were in some measure due to melting glacial ice. Whatever the source of the water there was a very evident increase in cutting power due to change in velocity as the water passed down the inclines. Whatever allowance may be made for mechanical abrasion, there will still be left a large part of the difference in depth which is due to solution. We may hold this to be another example of differential solution — due not to difference in character of the rock mass but to difference in rate of motion of the solvent.

Where the axes of dentpits are parallel to the bedding planes their surfaces are often crossed by thin laminae containing a large percentage of silica. If solution were the only process used in their formation such laminae should form sharp projecting ridges, yet differences in bedding are so little expressed through relief as to be either not at all noticeable, or to be barely felt by the finger tips. Mechanical abrasion thus seems to have been present at all times.

The sharp edges of the intersections of confluent dentpits at once

Plate 14



Surface of a roche moutonnée about 200 meters north of the north end of Beekman street, Plattsburg, N. Y. Shows rill channels whose rapid deepening is due to greater speed in motion of solvent. From a photograph taken November 1909

demonstrate the fact that no abrasive particle used could have had sufficient mass to enable it to escape from the vortex and cut across this border. On the other hand it has already been pointed out that the water during great storms is never noticeably discolored where these dentpits occur, and that the lake bottom has been swept clean of all fine material for considerable distances from the cliff. The water is not bringing in silt to use in its attacks upon the cliff, but it is in fact removing, through the agency of lake currents, all those particles which are fine enough to remain any considerable time in suspension, and leaving them where the present lake does not have the power to pick them up again. Thus we must conclude that abrasive material of sufficient fineness to do work of this character is apparently conspicuous only by its absence. Some fine abrasive material must however always be present and to such inorganic particles as may be brought, detached, or allowed temporarily to remain, we must add such organic particles of the plankton as the calcareous carapaces of microscopic crustacea and the silicious frustules of diatoms.

There is a border land between solution and abrasion that is but little understood. The points of contact between any two masses may be considered as molecular rather than molar and differential motion between the two masses might detach single molecules as well as clusters of molecules. Increasing speed of molar motion introduces new conditions and unexpected results. A tallow candle is driven through an oak plank; water is made to cut rock in hydraulic mining; our great breech-loading guns, used in warfare, are short lived because escaping gases driven with great velocity cut away the metal around their breach mechanism. The energy of an ounce of hydrogen moving with the velocity of a thousand feet a second is precisely the same as that of a steel ball of same weight and velocity. A stream of molecules driven against a solid may detach not only molecules but masses as well. We may get some idea of this from tornado destruction. Note also the action of air on swiftly moving meteoric bodies. We may then be justified in concluding that there is such a thing as molecular abrasion, that it is a fact to be dealt with in nature, and that it has played a part in the formation of dentpits.[1]

[1] For erosive power of escaping gases on guns *see* Ordinance and Gunnery, by Col. O. M. Lissak, page 260.

For statement that "The erosive effect of the gases appears to depend more on their velocity than on the maximum pressure" *see ibid.* page 550.

One additional point should be made here. The condition of the molecular film of water next any soluble substance must at least be as complex as its molecular film in contact with the air. In the film next the rock surface for instance, there are molecules of water passing into the rock and molecules of rock passing into the water. This film may have exceedingly tenaceous properties, and the greater the difficulty of removing it, of freeing the separate ions or molecules in it through diffusion, the slower will be the process of solution. When the solvent is thrown into rapid motion against this film it not only helps to tear it away but some of its energy is transformed into heat and electricity and before dissipation can take place such transformation may very materially accelerate the process of solution itself. In other words these forces may supersaturate the film while they are in action and relief will be found in forced diffusion aided by mass motion. We may therefore hold for the present that dentpits are the result, in part, of differential solution, due to differences in motion of the solvent; and in part also to molecular abrasion and abrasion by molar particles of exceedingly small mass.

Comparison of potholes, cupholes and dentpits. In pothole formation we have large and comparatively constant vortexes which are capable of moving large pebbles and of giving them a rotary motion of considerable radius. These factors determine size. Gravity plays a very important part in their formation for it determines the direction of the cutting, holds the heavy tools against the bottom with considerable force, and does not allow the vortex motion to lift them and use them against the upper and older portions of the excavation. The side cutting is continued by finer material but the bottom cutting is so greatly in excess of it that deep rather cylindrical holes with well rounded bottoms result. Sections along their axes will give somewhat U-shaped figures.[1]

In cuphole formation the vortexes are markedly intermittent in action, if not reversed, are much smaller, more closely packed together and incapable of handling heavy material. These factors again determine size and also number per unit of area. The part played by gravity is not so important although it still loads the vortex points, determines the direction of their cutting and keeps their axes vertical.

[1] Giant kettles do not differ much from potholes in the manner of their formation though they do in the agent employed and in their size and distribution.

Gravity also still aids in holding the cutting material against the surfaces, retains it there when motion ceases, and adds new material thereto from the water and the air above. On account of the fineness of this material the vortex holds most of it in suspension as an air vortex does dust, and while it cuts down at its apex, gravity is powerless to keep the greater part of the load there and a very marked widening of the older portion of the cut is allowed to take place.[1] Sections along their axes therefore give us somewhat V-shaped outlines but the sides are never straight lines and the figure is more nearly that of a parabola or hyperbola.

In dentpit formation we are dealing with still smaller vortexes and usually with a greater number per unit area. If the vortex is acting against steeply inclined or overhung surfaces at some distance from the bottom, or source of load, it will be able to use only such abrading material as is already in mechanical suspension in the water or which may be supplied to the vortex through the action of vertical currents or through detachment from the rock surface. The deeper the water the finer will the particles be that the vortex is allowed to use. Instead of pressing the abrading material against the surface, as in pothole and cuphole formation, gravity is always working to keep such material away from overhung surfaces and is constantly trying to withdraw from the grasp of the vortex all particles whose specific gravity is greater than that of the water. The material used must therefore be somewhat uniformly distributed throughout the vortex rather than loaded in or confined to a smaller portion, that would thus be itself drawn down by gravity, and the cutting in consequence will be less localized and confined to no one direction. In other words, one portion of a vortex can not cut more than another because of greater load, unless the vortex segregates its abrasive material through centrifugal action, and if so segregated, the result would be a cut showing that widening is carried on greatly in excess of deepening, and this is the form of cut that we actually find. The fact that the effect of gravity on the sediment is here made a negative rather than a positive quantity is in itself a distinction which places dentpits in a distinct class and we must see that they really differ more markedly from cupholes than do the latter from potholes. We may also note that when this cutting is on overhung or nearly vertical surfaces gravity does not allow abrasive material to remain on

[1] It is in this manner that cupholes, such as those shown in State Museum Bulletin 133, plate 4, are cut in the sides of steeply sloping surfaces.

the surface when motion ceases, and brings no new material to this surface during intervals of rest. From the aspect of the question in regard to the influence of gravity we might be led to assert that while potholes and cupholes can be cut only downward, dentpits can be cut in any direction but downward; and under all ordinary conditions the statement would be true. We have seen however in plates 12 and 13 that where waters are comparatively pure, typical dentpits may cut very nearly downward. Where waters hold no particles heavy enough to allow the influence of gravity to become positive and thus interfere with the tendency of the vortex to whirl them freely about, there is no apparent reason why dentpits might not be cut directly downward.

That the recognition of dentpits may become a matter of no little importance, will be seen if we consider them for a moment in their relation as geological timepieces. Niagara has long since become a classic in this respect, and while we realize that the time problem is not so simple as it was first thought to be its value is greater today than ever before and its accuracy as a timepiece will be more clearly understood in the near future than it now is. Giant kettles must be cut with a speed which is in some respects comparable to that with which cauldronlike cavities are excavated at the foot of falls where vortex motion is both great and rapid. The cutting of potholes is a much slower process. When we come to cupholes we are dealing with phenomena which require a very much longer period in which to produce any marked result. The intermittent character of the vortex, its small size, the fineness of the material used, the slight pressure allowed the abrading material at the cutting point, these and other things make the above conclusion an inevitable one. These cupholes show conclusively that at no time since the recession of postglacial Lake Vermont has the water surface remained at any one level so long as it has remained at the level on which these cupholes are cut. Now in dentpit formation we must remember that we are dealing with smaller vortexes and with abrading material so fine that gravity can give it no pressure whatever on the surface undergoing the cutting. This abrasive material is not only exceedingly fine but there is in amount not $\frac{1}{100}$ of that which is allowed or used in the cutting of cupholes.

Keeping in mind the statements just made, let us examine the shores of Valcour island. Where cupholes have not become confluent they are cut on distinctly glaciated surfaces and their

depth rarely exceeds 10 centimeters. Where dentpits have not become confluent they may also be found on glaciated surfaces and the markedly slower process of their formation has rarely allowed them to penetrate to a depth greater than 1 centimeter. Scattered dentpits on an undoubtedly glacial surface may be seen in plate 4, on the smoother surface of the rock and about half way between low and high water. Foreshortening makes them appear as ellipses. A little above this belt and near the extreme right a few more nearly circular outlines may be detected. These dentpits are of precisely the age of the cupholes and both were started on glacial surfaces when the water was lowered to near the present level. Now, just inside of the mouth of Bat cave in the opposite wall of the channel and at the same level, we may also find a few separate dentpits but much better developed than those on the wall outside. Where cupholes have become confluent they have of course destroyed the glaciated surface. In these regions of greater activity the surface may have been cut away to an average depth of perhaps 20 centimeters. Likewise with dentpits, where confluent, the vortexes producing them were the more numerous and stronger and the amount of surface removed may have been as great as 2 centimeters. This is the condition of the cave wall shown in plate 11. Now as this cave is more than a meter wide it follows that *in all its essential features it is as old as the glaciated surfaces on which the dentpits are cut outside.* The recognition of these dentpits and a knowledge of their rate of formation thus enables us to decide a very important question and the answer is evidence of the strongest character for preglacial or interglacial Lake Valcour.

As dentpits stand in such an intimate relation to solution it will be important to consider next this factor in the formation of the Valcour island caves.

Solvent power of Lake Champlain on its limestones. Cystid point, on the southeast shore of Valcour island, seems to be caused by the presence of a fissure, and the little cove just south of it is filled with movable rock debris to a depth of about 2 meters. On either side of this cove the shores consist of bare rock. Suspecting the eastward extension of a fault here, I have made an examination of the visible lake bottom from a rowboat on a perfectly still day at a time of low water in the fall of the year. The condition under water was much like that noted on the exposed shore. A depressed belt over the fissure was covered with boulders and pebbles of various kinds and sizes while, on either side of this, large areas of

bed rock were free from loose material. At some distance from the shore the material covering the belt was such as we should expect to find in a region of washed till. The belt was here neither so wide nor so thickly covered as it was on the exposed shore. Wave action had evidently assorted and built up the shore deposit but the deposit under deeper water seemed to have suffered little if any movement.

Under about a meter and a half of water we noticed a pebble about the size of a cobblestone which was resting with its bedding planes in vertical positions and which appeared to show the results of differential solution in a rather interesting manner. The arrangement of its alternating layers of very fine silicious and calcareous sediments seemed strikingly like that of a peculiar bed found on the island only in the weakest part of the Camarotoechia shales. Its calcareous layers had been dissolved or eroded to considerable depths, leaving the projecting silicious layers as an index of the former size and shape of the pebble. One aspect of this specimen is shown in plate 15.

When broken from its bed, during the last glacial period, or when separated from the larger block of which it may have formed a part, it evidently had the form of a four-sided prism with faces of unequal area. In our figure it is resting on the remaining portions of the largest of these former faces, which is much foreshortened in the view, and it has what is now left of its former smallest face, at the lower front. The latter face has been wholly lost from the softer portions of the stone and these now possess an acute angle in place of it. This prismatic form was considerably modified, during its movement with the till, but was not wholly lost. Glaciation seems also to have added a few facets.

Any marked wave or water action on this specimen must have been absent during the existence of Lake Vermont and the Hochelagan sea, for those were times of deposit in this locality. When Lake Champlain began work at nearly its present level it had first to remove these later deposits and wash out the finer material of the till before it could begin to work on what then must have been a smooth glaciated pebble. The cutting out or the dissolving of the softer portions of this stone must therefore be purely the work of Lake Champlain and of no older body of water. Its study should yield testimony of great value as to the ability of this lake to have formed the series of caves which now lie along its Valcour island shores.

Plate 15

One aspect of a glacial pebble which has lost much of its substance through differential solution and erosion by Lake Champlain

We may first note the exceeding thinness of some of the retained silicious laminae which now project in places as far as three or more centimeters beyond the surfaces of its calcareous layers. The edges of some of these sheetlike extensions are so fragile that they were broken in several places during the careful handling which the specimen received before being photographed. The edge of one recent break may be seen in the middle thin sheet of plate 15 and is shown in plate 16, figure 2. That these and other fragile edges had been preserved shows conclusively not only that the specimen had not been rolled by wave action for ages but also that wave action had not been able to roll or throw smaller pebbles against these edges since they were formed. This witness against the power of wave motion in this locality to use small pebbles as tools of erosion would lead to the conclusion that this specimen, when found, was resting on the same base on which it rested at the time of cessation of motion of the last ice sheet. This may be true, but there are two different times in which this pebble may have been moved and it will be well to note them. The bare areas mentioned may have been first cleaned off by subglacial drainage moving under pressure and the pebble may then have been removed from the till to find permanent lodgment in the more sheltered position over the fissure. If not moved before the ice front passed to the north it could not have been moved until the waters of Lake Champlain had arrived at approximately their present level. While Cystid point is somewhat sheltered from storm action yet it is no easy matter to land here in a rowboat during strong north or south winds. Waves of exceptional force may have swept the till from the bare areas mentioned and moved the pebble to the deeper and better protected position in which it was found. Whether left in this position by the ice sheet or moved thither during either of the periods mentioned above, it could have been subjected to solution or abrasion only since the deposits of the Hochelagan sea were swept away. If for long ages wave motion had been unable to use small pebbles against its thin edges it must have been unable even once to turn this specimen over during that same long period and the erosive features we are about to notice will yield strong evidence in support of this conclusion.

One face of the supposedly dissolved portions of this specimen is unmistakably marked by typical and confluent dentpits with

widths of about 10 millimeters and depths of from 1 to 2 millimeters. The presence of dentpits shows us at once that these softer layers have not been cut away by simple solution but that erosion at the hands of vortex motion has played an important part in the process. Remembering also that dentpits show absence of cutting vortex points loaded with sediment by gravity, we find them in this case indicative of surfaces which can not well have been upper surfaces. The two surfaces on which these dentpits appear are both on the underside of the specimen as it is shown in plate 15, or on the broadest face of the present three-sided interior prism and are only separated from each other by the thin silicious sheet of the middle bedding planes. As in this plate the specimen is resting on the remnants of its older prismatic face of greatest area, which was the position in which its center of mass would be lowest, it would appear that these surfaces were not only undersurfaces when found but that they had been such during the whole age of Lake Champlain. These two dentpitted surfaces of the softer beds of the stone have been cut by abrasion and solution together until they are now 27 millimeters distant from the outer edge of the harder layers or from the probable surface of the stone as the last ice sheet left it. This aspect of the specimen is shown in plate 16, figure 1.

The surfaces of the soft beds which are opposite the surfaces just described are indented with numerous, more conical pits, measuring from 2 to 3 millimeters in diameter and having about half that depth. The cutting here is of the type effected by vortexes whose points are down, and kept filled with sediment by gravity. Though the dimensions of these cuts are so small, they have lowered this surface of the specimen some 55 millimeters. As cutting of this type can take place only in a downward direction the surfaces of the specimen on which they appear must have been upper surfaces. These are the surfaces uppermost in plate 15 and the greater rapidity of the cutting on this portion of the specimen only served to lower its center of mass the more and make its equilibrium still more stable. These surfaces have very probably been upper surfaces ever since the cessation of motion of the last ice sheet. This aspect of the specimen is shown in plate 16, figure 2.

The character of the two soft layers does not change on passing from one side of this stone to the other and the difference

Plate 16

Fig. 1.

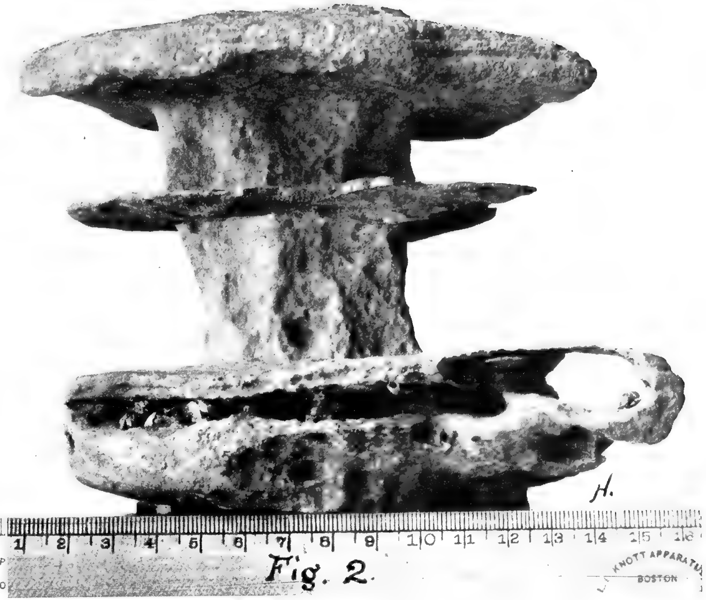


Fig. 2.

Two views of a water-eroded pebble taken from a little over a meter's depth below lowest water of Lake Champlain.
Figure 1 shows the under surface of the soft beds to have been cut by water vortexes in such a manner as to leave small though typical and confluent dent pits.
Figure 2 shows the upper surface to have been cut by many exceedingly small but loaded points of water vortices.
Specimen now in the New York State Museum

in the depth of the cutting is due purely to a difference in the action of the environmental forces. When this specimen was first taken from its resting place no attention was given to its position on the bottom other than that its bedding planes were vertical. In other words it was not noted which side was uppermost. The two distinct types of erosive action we have been discussing have, however, enabled us to very positively determine this matter some years after the date of collection. Not only have they done this but they also have strengthened the conclusion, drawn from the thin edged laminae, that this stone had never been moved by the action of heavy seas but had remained with its dentpitted surface down for several thousand years.

It may here be noted that this pebble yields information of yet another variety. That the floors of many of our caves are a meter or more below the present lowest water level of the lake would in itself be evidence that this lake did not cut them unless it had for a long time been at a lower level than the average of the last hundred years. Now it could not have been that meter lower without having brought the specimen we have been discussing so near to the surface that the waves of storms would have used it as a plaything, deprived it of its thin edges, destroyed the remaining evidences of its former angular outlines and made of it a simple beach pebble. Its fellows would also have been so changed in position as to bear witness of the segregating power of wave action. Our pebble thus yields evidence that goes to prove that the surface of Lake Champlain has never been materially lower than it was in November 1908, and never before perhaps so low.

The old benchmark in Shelbourne harbor made in 1827 marks the exceptionally low water reached that year. Not till 1881 was this mark passed and a new record established. In November 1908 this was again passed by about 2 inches. As the pebble we have discussed is in itself testimony that the lake has never been lower since the period of the Hochelagan sea and as it bears on its surface an index of the work accomplished only since the present lake waters were low enough to uncover this pebble, it becomes in itself a timepiece showing the age of Lake Champlain. In other words this pebble presents clear evidence which goes to show that on the melting of the ice sheet, isostatic balance was quickly restored in this region and a position close to a former water level, that of Lake Valcour, was rapidly recovered and has since been held.

Let us now take the evidence this pebble has to offer concerning the question of cave formation. As it has rested at a level close to that of the floors of many of these caves for just as long a time as Lake Champlain has been in existence, it should be able to offer a fair measure of this lake's capacity to dissolve its limestones and to erode them through dentpit formation. At Cystid point these two agencies have cut comparatively pure limestones to the depth of but 27 millimeters. It does not seem likely that the deeper purer waters of Paradise bay could, in a more sheltered position, have cut to greater depths during the same period. Many of the caves of this region, however, represent a cutting more than 75 times as wide and several hundred times as deep. Portions of their walls are out of water for more than half of each year and are then free from any action of this nature, but the pebble has remained under water for every moment of every year. The results of this comparison are very striking and perhaps are not wholly fair. It may be urged that vortex action would be stronger and therefore more effective in shallower waters. This may be true, but the greater depths of the caves have also been subjected to this action for every moment of every year and under this depth we shall probably be again dealing with vortexes whose strength is no greater than those of the pebbles' level at Cystid point. Most of the cave walls maintain their wedgelike shape and become wider as the limit of low water is reached. Weighing carefully the evidence, we shall make ample allowance for the results of these two features of wall cutting if we credit them with the removal of between 2 and 4 centimeters of surface during the age of the present lake. The evidence of the pebble is therefore to the effect that Lake Champlain has been at most but a modifier of a belt of old caves which were very evidently left here by an ancestral body of water.

Valuable as has been the evidence this specimen has given us, it has yet failed to show that for which it was taken from its position of long rest. In other words it has failed to clearly show the amount of solution accomplished by the present lake. We have merely found a very definite limit which solution could not have reached in the time involved. It should be allowable however, and helpful as well, to make an approximate or tentative estimate of the share each agent has accomplished in this recorded work. As a whole, abrasion is a much more powerful agent than

solution, but we are on very uncertain ground when the abrasive material used is as fine as it must be in this case; and also when its particles are so much freed from the influence of gravity. The practical absence of evidence for differential solution on dentpit surfaces, however, is a very good indication that molar abrasion is here still the most important factor. We may allow it at least two thirds of the 27 millimeters noted. The remaining 9 millimeters will then become an index of an utmost limit for the amount of erosion accomplished by molecular abrasion, solution in presence of a rapidly moving solvent, and solution in a quiet solvent or where molecules and ions can escape from the contact films only by diffusion or movement induced by gravity.

As the rapidly deepening rill channels on roche moutonnée slopes are by themselves strong evidence of the powerful influence of a rapidly moving solvent, and as our previous discussion shows that we should expect it to be such in both this type and in dentpit formation, we may assume that vortex motion through molecular abrasion, through bringing the greatest volume of water in contact with a given surface in a given time, through forceful detachment of portions of saturated contact films and through various transformations of energy, is responsible for at least two thirds of this 9 millimeters, and that quiet normal solution, relying on simple gravity or diffusion to further liberate the molecules which have passed into the contact film of the solvent, is responsible for not more than 3 millimeters of a surface on which it has been acting for 50 centuries or more, which is the time we may temporarily assign for the age of Lake Champlain.

While, therefore, solution may have played a very important part in the formation of these caves, it was very certainly not solution by the waters of our present Lake Champlain.

Additional evidence as to the effects of solution is to be found in Sloop bay. At the foot of a cliff which terminates the horizontal depth of the bay there is exposed a wide glaciated shelf which dips gradually southerly and enters the present waters of the lake. The higher portions of this shelf are still covered by till and show the usual scratched and polished surface of the rock, when uncovered. That portion which has longest been uncovered, save at highest water of spring floods, has been acted upon by expansion of water freezing in its joints and bedding planes, and large blocks have been loosened to be pushed about by shore ice or dragged seaward by ice blocks during the breaking up of the lake in the spring.

As the shelf approaches low water it reaches a level where the action just described is inoperative, and the surface sheet of rock has not been removed. This surface sheet is swept clean of sediment and is much as the ice sheet left it. The bed here had its constituent sediments assorted by vibration of the bottom waters of the Chazy sea, due probably in part to wave motion on the surface and in part to tidal flow of waters over the surface of the sediments. A series of interlocking ridges containing much silicious material were thus segregated and the bottoms of the miniature valleys between filled with the finer and purer calcareous material of the bottom. Solution aided by mechanical attrition has carried away the exposed softer portions of this bed to a depth frequently measuring 24 millimeters and sometimes slightly exceeding this depth. A view of this shelf at a time of low water is shown in plate 17. The ridges remain as flat surfaces of irregular outline. Abrasion has removed the glacial polish and finer striae from these surfaces and there is a slight relief of a fraction of a millimeter in some places which reveals figures like branching algae with stems from 2 to 6 millimeters in diameter. The amount removed from the higher surface can not well be more than 1 or possibly 2 millimeters, the average loss of surface from the softer and harder portions being in the vicinity of 15 millimeters. The bay opens to the east and there are no strong winds from this direction in this region. North or south storms disturb the waters here but very little. The bay however has a muddy bottom and storm action enables its waters to take up enough sediment to become discolored. At such times small and gently moving waves with an abundance of fine abrasive material must lap this area. Careful examination of the lowered surfaces of the rock plainly show the presence of water vortexes carrying silt. The difference between the 55 millimeters of the block last studied and the 24 millimeters of surface removed here must be largely due to the great difference of wave energy in the two localities. Whatever part has been played by solution in the lowering of the Sloop bay surface has been aided in no little measure by plant action for blocks taken from this surface show a dried organic film still attached to the very irregularly pitted surfaces of the depressions. The depth of 24 millimeters is not to be found next the harder ridges but near the middle of the softer area. Solution alone would have worked with greater uniformity. As in even the lesser depths, erosion by vortex action is still a factor, it hardly seems possible that pure solution could have

Plate 17

From a photograph of a rock shelf in Sloop bay, taken during low water on September 29, 1906. The solvent powers of Lake Champlain, aided by mechanical abrasion, have cut the softer portions of this shelf to a distance of between 2 and 3 centimeters below the former glaciated surface.

removed more than a very few millimeters of this surface. Now the periods of time involved in the cutting of the dentpits, the softer layers of the pebble from Cystid point, and the softer layers of the rock shelf here are practically equal, for the phenomena occur along the same horizon. When once the waters of Lake Champlain had reached their present level it would not take shoving blocks of ice very long to clean off the Sloop bay shores and leave them very much as we now find them. The amount of rock surface removed by the solvent action of the incessantly changing, and far from saturated, waters of Lake Champlain is shown by these studies to have been remarkably small.

A still more conclusive bit of evidence concerning solution is to be found along the more southern portion of the west shore of the island. There is a line of low cliffs along a considerable portion of this shore, and it often rises several meters above low water. These surfaces are exposed to wave action from seas raised by westerly winds. Such waves here carry little sediment owing to the deep water and clean rock bottom just off shore. That these waters are deep is indicated by the presence of the ruins of an old dock here at which the largest lake steamers used to stop to take on wood in the days when that was the available fuel. A view of this region is shown in plate 18. The long oval rock basin of the foreground, considerably foreshortened in our view, is but one of a number of such basins cut by the till on the old shore line of Lake Valcour. The debris seen in the basin has been derived from higher portions of the shore line through the effects of freezing water in joints and bedding planes, and the action of shore ice. The amount of the destructive work of Lake Champlain on this older glaciated shore line may be easily seen. The principal, and by far the greatest cause of loss, has been due to the effects of freezing water in joints and bedding planes and the subsequent removal of the loosened blocks through the action of shore ice. The material now lodged in the glaciated basin is a portion of the material which was so derived from the surface above. Wave action itself, even with the load of tools here present, has been rather an unimportant agent and has not been able to modify appreciably the basin in question. A nearly complete portion of an old glaciated outline of this ancient coast may be seen where the figure is present. One block has been removed from the surface on which she is standing but much of the old glaciated surface remains above and to the right of her head. The shelf on which the boat rests has been

somewhat cut by cupholes. The edge of a still older, upper terrace, which Lake Valcour was destroying, may be seen directly above the head of the figure. The old steamboat dock is hidden in the second cove beyond the boat. In plate 19 we have a view in this region taken farther to the north and near the position of the old steamboat dock. Another glacial basin, partly filled with rock debris, is here shown. The rock boss at the right of it has not yet lost its glaciated outlines although freezing water has detached one block from its surface and the movement of shore ice has drawn it a little outward. We have here a practically unbroken glaciated outline reaching from low to high water. While the lake was yet above its present level the side of this boss facing the lake must have lost the sediments with which it may have been covered. Its surface has been exposed to the action of solution throughout the age of Lake Champlain. While the movement of loose material on this surface has destroyed glacial striae yet such striae may be seen on surfaces at the same level just south of this. There are places here that have not lost 5 millimeters from their former polished surfaces and we are obliged to limit the solvent power of the lake waters to a figure at least as low as our estimate made from the study of the pebble taken from Cystid point. If one is still in doubt as to the correctness of this estimate let him examine again the west side of Spoon island as shown in plate 4. The unbroken glaciated surface shown there runs from below lowest water to above highest water After allowing for loss of surface at the hands of various agents active here, what will you have left for simple solution? The well developed caves of plates 1 and 10 lie between 60 and 180 meters from this face and on the same level. What part has solution, at the hands of Lake Champlain, played in their formation?

Before leaving this question of solution we should call more definite attention to an agent we have but mentioned, and that is the influence of living or decaying green algae, sponges and micro-organisms. If we again examine plate 9 we may note that this surface of the Lowville block has a border of dentpits which distinctly show the effects of differential solution brought about by the above cause after the block had fallen from its bed. Nearer the center of the block there was not light enough to support plant life and the dentpits of this region have suffered but little change though there are a few thin seams of less solvent material running through the block that have here formed very

Plate 18

A view of a portion of the southwest shore of Valcour island, showing some of the glaciated outlines of the older shore of Lake Valcour. From a photograph taken in August 1908

Plate 19

View of a portion of the southwest shore of Valcour island from a photograph taken October 16, 1909. Shows a practically unbroken glacial outline from low to high water. The point just beyond the glaciated basin is a part of the wave destroyed, old steamboat dock.

fine and slightly raised lines which follow the rise and fall of the dentpit surfaces. Such elevations on the general relief of this surface are in no case greater than a fraction of a millimeter. This type of solution is due to organic acids produced by resident organic forms, and is chemical in its nature. The cave walls are protected from this agent, save in an indirect way, for they are shielded from light. The lake waters themselves of course hold carbon dioxid in solution and the supply is constant and from various sources. It has no doubt markedly increased the solvent power of Lake Champlain waters but its effects lie within the limit of the 3 millimeters already set as the greatest limit of quiet solution since the recession of the Hochelagan sea.

Effect of expansion of freezing water. We have already called attention to this most powerful of all the disintegrative agents now at work on Valcour island in our remarks covering the features presented by plates 18 and 19. The vertical or overhanging front of the cliff shown in plate 1 is very largely due to this cause. In the *Fourth Report of the Director of the Science Division* [N. Y. State Mus. Bul. 121] plates 5 and 6, will be found two reproductions of this cliff from photographs which I made in the winter of 1903. Both views were taken from the ice surface shown in the foreground, and both contain a view of some portion of the cliff shown in our present plate 1. The ice curtains, which speak of frozen spray, have a very interesting story to tell of cliff destruction. The effect of this agent is here seen to be destroying caves instead of making them. The most numerous and most marked changes in temperature occur on the exposed faces of these walls. The waves break here and wet the surfaces to great hights. The lake waters themselves are rarely frozen over (save for a few days) until some time in January. The fall rains raise the level of the lake and many small cave mouths are covered in consequence. The water in these is never frozen. It is doubtful if the water in the innermost recesses of some of the large caves is ever frozen. Once well within one of the higher caves and we shall find wetting above the water line to be but a fraction of the hight to which it is wet outside. The dentpit etching on the inner wall faces speaks of their comparative permanence, as do also the rounded edges of the rock angles. On the outer face of these cliffs, where blocks have been split by freezing water, no surfaces are etched and all rock corners are sharp. At the south end of the island

where most of the Chazy beds are exposed there are but a few beginnings or remnants of caves in the very beds in which they should abound. The cutting back of the cliff by the process indicated gives the cave-forming forces but little chance to outrun it. On the shore represented in plate 1 the wave energy is much less powerful owing to the projecting capes to the south. Here outer destruction follows inner formation at a respectful distance. At long intervals a fragment of the side wall of the caverns some distance in may become dislodged and plate 11 shows several edges that could be easily removed. A few such have been found in the debris partly filling some of these caves. However large a part this destructive agent may have played with outside walls as we enter the caves its power is reduced with the distance to which we penetrate until finally it is entirely inoperative. It is widening the mouths of the caves somewhat and increasing their hight in some instances but it is doing nothing to carry them deeper into the cliff.

Evidence from preliminary excavation. The floor of Bat cave is deeply covered with blocks which must have fallen in greater part from the roof though doubtless there have been also many contributions from the side walls. An effort was made during low water of the present season to penetrate this mass and find the cave floor. The first blocks removed were very heavy and showed little trace of either solution or erosion. Some of the unmoved blocks of this layer may be seen at the lower left in plate 11. The material we removed was all carried toward the front of the cave and much of it thrown completely out. After getting down about a third of a meter the surfaces of the blocks began to show plainly the effects of differential solution, and at about a half meter this aspect became pronounced. For the next half meter the blocks had to be removed from under water and not a single block was found that showed the least sign of any movement in the mass. As a rule the lower blocks were smaller, but all possessed angular outlines and not one showed a rubbed surface. Some of these lowest blocks had edges so thin as to be easily broken off by the fingers, and all showed differential solution to a very marked degree. One specimen taken from the depth of about a meter was photographed, and a view of it is presented on plate 20. A study of the surface and edges here shown will convince any one that wave motion since the glacial period can have had no effect

Plate 20

From a photograph of a sample stone taken from about a meter below the surface of the material now on the floor of Bat cave. It shows conclusively that no one of these blocks is moved over the surface of another and that the cave is therefore not eroded through any shifting of this material. Specimen in possession of New York State Museum

whatever in moving the mass of material now in the cave. If other evidence were needed we could point out the fact that the dentpits extended down by the side of this debris as far as we made our excavations, and that the raised and sharp edges of intersection of the confluent dentpits were in no manner cut across or worn by any movement of the cave filling. Plate 11 shows a considerable portion of this uncovered face of the wall. The horizontal line a – – a separates the formerly exposed surface from that which we uncovered. The position of the camera was about a half meter above the surface of the filling and this will account for the apparent inclination of the lower lines of dentpits. Not only had no marks been made on this wall by block motion but the wall itself had been cut away from the filling so as to separate one from the other. We hoped to penetrate deep enough to see if this loose material rested on any undoubted glacial deposit but the limit of time available led us to cease further prosecution of this work for the season.

The material taken from the cave filling has itself some valuable evidence to offer. We have already seen that Lake Champlain has had but little effect on its rocky shores so far as pure solution is concerned. The material in this cave filling, at the depth from which the specimen illustrated by plate 20 was taken, shows a very marked amount of solution. An examination of this figure will reveal no trace of vortex action as an assistant factor in the cutting but it does show that the rate of removal depended entirely on the minutest differences in character of the bed material. Apparently no better example of pure differential solution could be desired. If there has been no help from mechanical abrasion, the filling at this depth is most certainly older than Lake Champlain. The absence of movement in the mass on this cave floor and the depth to which solution has acted on the deeper portions of the filling can lead to no other conclusion than that these rock fragments were in the position in which we now find them before Lake Champlain began to cut its present series of cupholes and dentpits.

The westernmost cave of the north wall of Paradise bay was next examined. Plate 21 gives its appearance as seen from the water edge at low water October 23, 1909. This cave is formed on a minor fault plane and close to it, both to the east and west, are parallel faults of small displacement. Freshly fallen blocks from the face of the cliff at (*a*) reveal nearly horizontal slicken-

sides. That there was some horizontal movement together with a slight vertical displacement is also shown by the neighboring faults. The cliff beds are much more fractured here than they are in the region immediately east, which is that shown in plate 1. As a result the cliff face has here receded to the north more rapidly and has left the less fractured face some meters behind. The latter plunges vertically into the water but the more rapidly receding portion has left in front of it a sloping beach which crosses the cave mouth at the cliff line. This recession and the position of the cave, which is well within the bay, both protect it somewhat from the effects of freezing spray though we still have the active work of freezing of water after cold rains in fall and spring and the freezing of water from melting snows. During storms the strong elbow of the cliff protects the recess from the grinding effects of strong wave action, and the fragments on the floor are but little rounded. Probably the fragments now on this shelf are comparatively new, for oblique wave motion would carry the more worn material into the recess at the northwest corner of the bay. Here we do find a mass of material that is all of limestone and has accumulated in this locality since glacial time. The writer first saw this cave in 1898. The following year he camped in its vicinity and converted it into a very serviceable dark room for photographic purposes. One large and well worn stone lay partially within the mouth and this was removed to make the interior easier of access. One had still to enter on hands and knees, though after penetrating to the horizontal depth of about 2 meters, one entered a rather roomy chamber in which several people could stand at the same time. The roof of this chamber is about 3 meters above the floor. Back of this first chamber there is another but the passage between the two is too narrow to allow of entrance. A few blocks were carried into the first chamber to support a board which was used as a dark room table. The waves of the following season moved several large blocks against the opening of the cave but did not disturb the stones placed on the floor of the chamber. For several years blocks have been thrown up in the front of the mouth during spring storms and often one or more has had to be moved in order to gain access to the interior. No large blocks have ever entered to any great distance into the cave. Waves have no doubt thrown smaller wave-worn pebbles over the larger guarding blocks and have moved these back and forth at exceptional times, but such

Plate 21

View of mouth of Darkroom cave and adjacent wall from a photograph taken from the lake edge on October 23, 1909. At *a* in the left upper portion we may see horizontal slickensides. The fault plane, on which the cave was cut, shows a slight downthrow on the right. The wall at the right shows for the greater part a surface produced by differential solution.

movement has not been sufficient to effectively cut the cave walls at their level. Material of this nature is also absent from the second chamber.

Late in the summer of 1909 a small excavation was made in the deposits covering the floor of the mouth of this cave. On digging down the size of the pebbles rapidly decreased, and numerous small and well polished granitics and quartzes were found among the limestone pebbles. At the depth of a few decimeters a thin layer of very fine and clean gravel was encountered and immediately under this was a fine and well oxidized clay containing a few pebbles so thoroughly decomposed that the peen of the hammer easily cut them and left half of the pebble imbedded in the undisturbed clay. The boundary between gravel and clay was very sharp and distinct. A block, or a projecting edge from the cave floor, now interfered with making a deeper cut in the small place chosen. The fine oxidized clay and the few thoroughly oxidized pebbles speak very decidedly for a deposit at least as old as that of the Hochelagan sea. We should also state that the buried portion of the cave wall was but a continuation of the exposed portion above. The cutting of the whole cave opening was thus shown to be older than the clay filling, and all subsequent erosion has hardly modified the opening. That this cave in all its essential features is at least as old as the glacial period must be considered as demonstrated beyond the shadow of a doubt.

Miscellaneous evidence. To the east of this cave is another which can be reached by boat or by the sinkhole shown on plate 2. The natural bridge between the sinkhole and the lake consists of badly fractured material. About 500 pounds of this rock were recently detached from its undersurface and allowed to fall to the cave floor in order to insure the safe passage of pupils doing field work in physiography. This cave is also cut along a fault plane parallel with that of Darkroom cave. One slickensided surface, by means of its well preserved diagonal lines, shows that the small vertical displacement (throw) was accompanied by a greater horizontal component. A view of the mouth of this cave has already been seen in plate 1. It is one of the few caves that have had their openings cut to the very top of the cliff. A careful examination of plate 21 will show that the same thing might easily have taken place there but for the fact that the wedge-shaped mass pinched in between the nearly parallel fissures has the smaller edge downward. In Bridge

cave, as we shall call the one we are here discussing, there is a similar wedge-shaped mass but toward the front of the cave the edge of this wedge was uppermost. There is some evidence in this cave that solution began its work on two nearly parallel fissures which were about a meter apart near the top of the cliff but which increased this distance to a little more than 2 meters in descending to the present low water level of the lake. This partition was subsequently cut away in many places. Dentpit action is at work cutting through the separating walls of smaller contiguous caves. Portions of these former separating walls are now left as pillars supporting the roof of a widened cave mouth. This cave has two items of proof to offer concerning its age, which differ from any we have yet mentioned.

Plate 22 shows a portion of the east wall of this cave in the region of the sinkhole. At (*a*) we have a portion of the older face of the wall removed by the action of expanding water in joint planes. The surface thus exposed is not a fresh one but has been subjected to a long period of weathering. We may note a still older surface of similar character under the overhanging mass at the right. At (*b*) we have what we may call an original surface or one not yet acted upon by the agent specified above. The deep etching which the edges of the very irregular bed surfaces have received and the much weathered edges of the finer laminae both speak of very great age, for the position is here a sheltered one. At (*c*) we have a portion of the wall of a cylindrical excavation which appears to have been cut by spirally descending waters. This cylinder opened into a basin which was more deeply cut in the side wall and which plainly speaks of water carrying abrading tools. Note also a portion of the deeply cut basin diagonally above this at the right which also emptied into it. Is any agent so cutting these walls at the present time? One answer to this question is to be found in the filling of this part of the cave for this filling has covered up a large portion of the lower basin and this it could not have done were any such cutting action now present. The filling is talus like and neither deposited nor modified by running water. Another answer and yet the same, is to be found in the appearance of the surface at (*c*) which shows its etched, irregular bed edges and its laminae nearly as plainly as at (*b*). The slight difference between these two surfaces is due to the fact that the recessed surface at (*c*) is now better protected, from even getting wet, than is the surface at (*b*). The very slight drainage this cave may now receive from rainfall or melting snows has had nothing whatever

Plate 22

View of a portion of the east wall of Bridge cave near the sink hole.
From a photograph taken November 2, 1909

to do with the erosion of the larger features here shown. The large chamber of Darkroom cave shows the same type of cutting by falling and whirling waters carrying abrasive material. No water whatever now enters the upper portion of this chamber. An examination of plate 22 will show that the descending streams which must have done this work were reflected and thus turned from one place to another either along the fissure plane or from one wall to its opposite. The shallow nature of the cut at (*c*) and the deeper cuts at the right of it and below it are due to such reflections of the falling stream. These caves present many other examples of the same nature and the evidence, in all its varied features, is wholly against any such cutting at the present time and wholly for a cutting which must have taken place many thousands of years ago. All of the cuts and the great chamber in Darkroom cave with its horizontal and cylindrical outlet, point irresistibly to the conclusion that we are here dealing with glacial moulins cut in older rock fissures.

This conclusion however opens up another field of great interest. At the time of the melting of the later Wisconsin ice sheet the rocks of Valcour island had been so far depressed by isostasy as to bring their highest portions below the level of the sea. If the caves had been modified by glacial drainage at that time, the waters passing through these caves must have completely filled every portion of them and been moved under great pressure. The leaping of such a drainage stream from side to side, cutting now more in this place and again in that (and cutting as if falling freely) would be out of the question. The effects could not have been so markedly localized as we now find them to be; but would have been of a larger and more uniform type. In order to find conditions that would yield the effects we have here noted we are compelled to go back to a time when the land was at least as high as it is at present. It is quite possible that we have in these cases a witness of moulin action at least as old as the earlier Wisconsin stage, if not older.

The next new item of proof offered by Bridge cave comes from an examination of its northward extension. The entire cave roof (the wedge between the two fissures) has been thrust down and fractured, as the result of great pressure above. A depression on the surface of the ground over the cave can be seen to run many meters to the north although now covered with soil and overgrown by trees and bushes. The only agent that could have forcefully thrust down this wedge is glacial ice.

A unique but important bit of evidence is found in the west wall of the narrow channel separating Spoon island from Valcour island. A rather high rocky promontory runs about east-northeast some 450 meters from the inner beach of Spoon bay. A block about 50 meters wide, cut off from the end of the promontory by a north and south fault, has been converted into an island, namely Spoon island, by erosion along the fault plane. Since the rocks dip southerly, and as the downthrow was on the east, Spoon island has apparently been shifted 100 meters to the north and forms a distinct barrier to currents moving easterly along the south wall of the bay. The imprisoned glacial ice and till of the Spoon bay basin would thus find their nearest and lowest southerly outlet lying along this fault channel, which is about 30 meters wide with high and nearly vertical walls on either side. The ice and till finding its exit here would be forced through under great pressure.

The northerly position of Spoon island with reference to the present end of the promontory soon allowed the till stream a free passage across the south end of the island to deeper and freer channels, and this eastward deflection was hastened by a well marked buttress on the middle of the east wall of the promontory.

That this buttress has been subjected to great pressure from the north is clearly shown by nearly horizontal pressure joints which cut diagonally across the beds and curve upwards as one follows them southerly. The caves shown in plate 10 lie just south of this buttress, and they must have been protected by it in a very marked degree. The rather small and northernmost member of this series of caves is located in the base of the buttress itself, and the pressure received by its northern wall was great enough to dislodge from it a rectangular block weighing some 300 pounds and thrust it southerly and inward against a filling of till. As the bottom of this cave lies some distance below the surface of low water, while its top is completely covered by high water, the finer material of its glacial contents has been washed away. The thrust-in block, however, still holds a number of imprisoned, glaciated limestone pebbles the size of cobblestones. As the upper and narrower portion of this cave is thus shown to have been filled with glacial till, we are again forced to conclude that all of the caves of this series are preglacial and that they have been but slightly modified since glacial times.

This cave offers very valuable evidence as to the solvent powers of Lake Champlain. Although it occurs in the purer dolomitic lime-

stones of the Chazy beds, postglacial waters have not cut back its walls to an extent that will yet allow the removal of the imprisoned pebbles. The block offers still more conclusive evidence, for though slight movements have enabled it to grind its own lower surface and the bed on which it rests, thus allowing water to have free access to its other surfaces, it has suffered but slight loss in size since glacial time. We have thus an additional proof which supports strongly our contention from other evidence that the present lake, through simple solution, has not removed material from its exposed limestone surfaces to a depth exceeding 3 millimeters.

There is yet another aspect from which we may view this cave question. Wherever the purer Chazy beds are exposed on the surface of Valcour island their unfilled master joints or fissures will be found to have suffered in varying degrees by solution and chemical action at the hands of surface waters. In some places these joints have been so widened along considerable portions of their length as to freely admit the leg of a man. In other places we may find joints whose faces seem to meet at the surface while they are separated in their deeper portions. Along such joints we find open circular holes in some instances small and close together and in other instances so large as to freely admit one's leg. I have been told that holes of this type have sometimes broken the legs of cattle, and I have noticed that many of these have been artificially filled or covered.

These dissolved joint crevices extend to depths of some 20 meters or more (65 feet and over). In Sloop bay, where a portion of the north wall has been quarried, these joint openings are seen to widen out into chambers which plainly show the effect of swiftly moving waters. Such opened joints with their inner chambers are often accessible to foxes and many of them have been used as dens.

We are now prepared to face a new problem. If our faith in the power of solution is great enough to allow us to conclude that surface drainage has accomplished all of this extensive joint opening since these rocks emerged from the Hochelagan sea, we must also conclude that during the longer periods of exposure which preceded the approach of the Wisconsin ice sheet joint crevices would have been acted upon by similar agencies, been cut down to former base levels and widened out into chambers far surpassing in size those now existing in this region. These two conclusions involve the making of a third as follows: To remove every trace

of these older joint channels (for our first conclusion asserts that the present ones are all new) we must further conclude that the Wisconsin till sheet cut away the tops of these isolated limestone hills to a depth even greater than the 20 or more meters now occupied by the existing system of joint channels. Now this third conclusion is one that can not be maintained and with it the first also falls. There seems to be good and abundant evidence that these hill tops were cut away by recent glacial action to a depth that rarely exceeded 2 meters, and even though we should allow more than five times that amount we should still expect to find the widened bases of the joint channels of the older period. Joint solution through the action of precipitated waters is an exceedingly slow process, and all that post-Hochelagan precipitation has been able to accomplish is a washing out of sediments accumulated during the recent period of submergence, and a very slight enlargement of the older channels. As the shore line caves are for the greater part but modifications of these old joint channels the preglacial origin of the one implies also the preglacial beginnings of the other.

The varied and cumulative evidence here presented seems to the writer to amply warrant the conclusion that both joint channels and caves are, in their larger features, preglacial. A few words concerning their origin may assist in more clearly comprehending the questions involved.

Origin and development

Where locally elevated regions have been unable to maintain a mantle of soil the surface rock is subjected to more rapid changes and greater extremes of temperature than where such a mantle has been allowed to accumulate. The effect of such changes tends not only to develop and maintain joint crevices, but it opens them at the end of the winter's cooling more widely and to greater depths than can occur in covered regions. At or soon after the time of widest and deepest opening the waters from melting snows and spring rains enter with great freedom, and after passing rather rapidly through them exit at lower levels thus quickly emptying all spaces not kept full by capillary attraction. These spring waters with a temperature of nearly zero degrees would contain more abundant carbon dioxid than summer waters, for the snow mantle of winter absorbs this gas not only from the air above but from the fracture zone below. The period of widest open crevices would

therefore coincide very closely with the period of most abundant flow of chemically active water. The deeper and narrower portions of crevices kept full by capillary attraction would lose no appreciable amount of water by evaporation on account of the small and protected exposed surface. Such waters while they might approach saturation would rarely reach it because each fresh filling of the space above the water surface maintained by capillarity would add mechanical pressure and force the older water out at lower levels, thus refilling the crevice with fresh water. As the expansion of the beds during the summer heating forced the crevice walls more closely together, a portion of the water held by capillary attraction would be forced to occupy new positions and would take its dissolved load with it. Evaporation would rarely be rapid enough to allow of deposit and the occasional advent of summer rains would furnish abundant fresh water and help to remove that more nearly approaching saturation. Fall cooling and the more abundant rain of that season in this locality would be very effective agents in removing material dissolved during the summer.

Exposed joint crevices, so situated as to receive surface flow, are thus gradually widened and deepened. Other joint crevices connecting with these might not receive so much water directly from the surface but they would help to carry the subterranean flow and become also widened. As the system developed the waters would move in certain channels with greater freedom. Dust and disintegrated particles accumulating on the exposed rock surface would be swept by rainfall into these openings, and the effects of abrasion would be added to those of solution. Joint crevices thus become joint channels. As these are widened they admit the cold air of winter in greater volume and the circulation maintained at this season serves to more effectively chill the rock mass and thus open the crevices to greater depths. As these channels approach local grade (determined by the level of a surrounding body of water or by the water table of the mantle rock flanking these regions) the deepening of the crevices ceases, but lateral cutting is continued. Such basal widening of the system is an indication of maturity.

Such work must be exceedingly slow, for the water supply is only such as falls on the very limited area in question. The waters doing the work would be free from humus acids on account of the bare character of the rock surface. Expansion of freezing water would be effective near the surface, but the depth at which it could be considered as an important factor would be very limited.

If the temporary base level was determined by a surrounding body of fresh water, as it appears to have been in the case of the Valcour island elevation, the exits of the joint channel system of drainage would be under the influence of a greater number of erosive agencies than the inland portions of the same system. Solution would be incessant, the solvent would be always in motion, and it never could approach a condition near saturation. The presence of light would permit the growth of lowly organized plants and animals, and their metabolic processes while living and their decay at death would both favor the process of chemical solution. If we will compare the effects of simple quiescent solution by thin water films approaching saturation with the effects of chemical and mechanical solution by incessantly acting and constantly moving waters of great volume, we shall see that this difference in erosive power would of itself turn joint-channel exits into water-level caves. To this means of differentiation we must add the influence of wave motion. This agent does work of very varied character from that accomplished through sliding or rolling of heavy blocks or the throwing of pebbles taken temporarily into suspension, to the work of broken wave vortexes holding solid particles so fine as to be almost in a state of permanent suspension. The submerged condition of the cave floors on Valcour island has protected them from the more energetic types of wave erosion, but the effects of vortex work are very manifest. Expansion of freezing water in these joint-channel exits is also a factor productive of widening. As a result of these agents of erosion the joint-channel exits become caves which narrow toward their roofs and rapidly narrow to channel dimensions as they enter the rock mass.

While the foregoing discussion outlines the probable history of formation of the larger shore-line caves of Valcour island, it does not account for the formation of the majority of the smaller openings for these do not seem to be connected with joint channels.

If a narrow joint crevice, so situated as to receive little water from rainfall in its higher portions, is bathed below by lake waters, such waters will tend to fill the crevice by capillary attraction but will at the same time receive all dissolved material and tend to maintain a fresh-water filling. As the lower portion of the crevice is thus widened the hight to which the water filling is maintained is lessened, but a new factor comes into play, for the effect of wave pressure in filling and emptying the crevice becomes now more pronounced and allows of more rapid changes in the filling. So soon as the breach becomes wide enough to permit water vortexes

to act on its walls, dent-pit action commences, and all other local agencies become more effective. As these caves thus work their way back from the coast line the air in them is at times compressed by storm waves which break against and cover their mouths. A large portion of this compressed air thrusts out a volume of water at the upper portion of the cave mouth with great violence, and the tops of these spouting caves are thus cut into the form of an arch. A portion of this air, however, with its contained hundreds or thousands of dust particles per cubic centimeter[1] must be discharged backward into the open joint crevice with considerable initial speed and thus serve to widen its proximal portions and allow freer entrance of water to these portions at times of high water.

Joint channels and joint caves were more or less modified during the last glacial period. With the advent of this period the outer portions of the rock mass were gradually lowered in temperature, and a condition of permanent frost came to occupy the joint channels. These were thus filled with ice before surface movement of the ice sheet became an effective erosive agent. In many localities in the glaciated regions of North America there are deep fissures or cavernlike openings which were so filled and which still contain glacial ice. The ice filling of these joint channels saved them from being filled with mantle rock when the ice movement began and saved them also from a later filling of till, though they received a till covering. The loss of material from the underside of some of these till coverings is now made manifest by a sinking surface over certain joint channels or by small sink holes like that shown in plate 6.

At some time during the glacial period subglacial drainage must have been comparatively free on surfaces now some 600 feet below the highest level of Lake Vermont (Glacial Lake Champlain)[2] else it is hard to conceive how giant kettles and rill channels (cut by surface flow of glacial waters) could be now found in this lower region. During such a time of elevation (at least to a degree as high as the present) subglacial waters found their way into wide joint channels through narrow surface openings and these were rapidly cut into circular shape by spirally descending waters. Some of the larger caves were thus occupied for a brief period by rap-

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[1] *See* Aitken, J. On the Number of Dust Particles in the Atmosphere. Roy. Soc. Edin. Trans. 35:1 (1888); *see also* Nature, 37:428 (1888), 40:394 (1890).

[2] *See* Woodworth, J. B. Ancient Water Levels of the Champlain and Hudson Valleys. N. Y. State Mus. Bul. 84, p. 195.

idly moving subglacial streams and their walls still show the effect of these moulins [*see* pl. 22].

The old relation of these joint channels to surface drainage has also been in part changed by glacial erosion, for wide open channels may be often found where they now receive little surface drainage, and undrained surface basins may occur at no great distance from them.

The movement of the till sheet along the east and west sides of Valcour island has modified many cave mouths, cutting away more from the lower portions of their southern walls than from their northern walls and thus leaving the latter the more nearly vertical. This effect may be seen in some of the wider cave mouths shown in plate 3. A moving till sheet would also cut away more rapidly at the cave mouth level, where caves were numerous, and thus tend to leave overhanging or convex faced cliffs, such as may be found on the east side of Spoon island.

During the occupancy of the region by Lake Vermont and the Hochelagan sea these joint channels and caves where not protected by an undisturbed till sheet were in part filled by fine though rather rapidly deposited sediments, and the whole tendency of these two stages was toward the preservation of the erosive work already accomplished rather than toward the inauguration of any new cutting of the old channels or cave recesses.

With the beginning of the Lake Champlain stage these old joint channels served again, though in a modified manner, their ancient function and the lake waters began an attack on the old cave mouths. This stage has existed for so short a time, geologically speaking, that it has produced but slight changes in the character of the older features.

It is becoming more and more manifest that the work accomplished by the last glacial period, although vast and tremendously impressive, did not obliterate so much of a former surface history as many geologists have been inclined to believe. Glaciated regions must be likened rather to a palimpsest from which a large portion of the older story may be recovered, and much work in this direction remains to be accomplished.

CONTRIBUTIONS TO MINERALOGY

BY H. P. WHITLOCK

Brookite

Indian Ladder, Albany co.

Brookite from a new locality in the Helderberg escarpment was noted on a specimen of calcite collected by Mr C. A. Hartnagel. Subsequent examination of the locality resulted in the collection of a suite of specimens of calcite which yielded on solution 10 small crystals of this mineral. The calcite vein from which these were obtained is situated at a point about half way up the cliff about 2 miles south of Meadowdale and ½ mile east of the road which ascends the escarpment from the latter village.

The crystals are minute, measuring from 1 millimeter to .5 millimeter in length. They are in every instance brilliant, with sharp, well defined faces and in general habit resemble those from Ellenville, Ulster co., N. Y. Figure 1 a and b shows the prevailing crystal habit. The vertical zone is much striated, due apparently to the development of vicinal prismatic forms. The following forms were noted on the seven crystals which were measured:

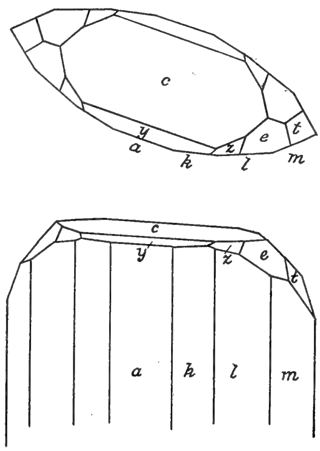


Fig. 1 Bookite, Indian Ladder

a(100), c(001), k(410), l(210), m(110), y(104), t(021), z(112) and e(122).

The following measurements served to identify the forms:

LETTER	ANGLE	NUMBER OF READINGS	MEASURED		CALCULATED	
			°	′	°	′
m : m′ . . .	110 : $\bar{1}$10	13	99	46	99	50
l : l′	210 : $\bar{2}$10	9	134	21	134	21½
k : k′	410 : $\bar{4}$10	10	155	54	156	14
c : y	001 : 104	7	15	37	15	40
c : t	001 : 021	15	62	5	62	6
z : z‴ . . .	112 : 1$\bar{1}$2	4	44	25	44	46
z : z′	112 : $\bar{1}$12	6	53	44	53	48
e : e‴ . . .	122 : 1$\bar{2}$2	4	78	38	78	57
e : e′	122 : $\bar{1}$22	5	44	19	44	23

Fluorite

Rossie, St Lawrence co.

Among the specimens in the New York State Museum collection is one worthy of notice, collected by the late Prof. Ebenezer Emmons, from Rossie, St Lawrence co. This specimen which measures 9 by 5 centimeters consists of a mass of rhombohedral calcite on which are implanted several compound crystals of fluorite of unusual habit.

These latter are built-up aggregates, roughly octahedral in shape, composed of minute individuals of hexoctahedral habit grouped in parallel position. The octahedral angles of the aggregates are in every case terminated by well developed superposed hexoctahedral crystals as shown in figure 2. The compound crystals are

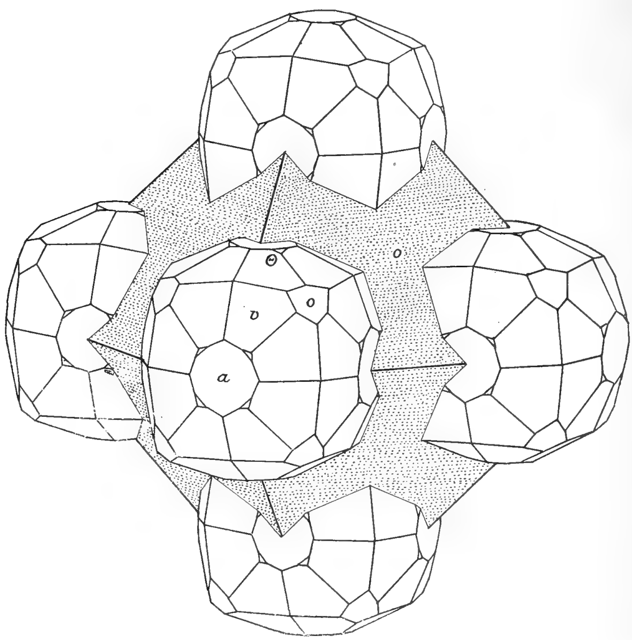


Fig. 2 Fluorite, Rossie

transparent, light green in color and average 15 millimeters in diameter. They are evidently of the same generation as the calcite in which they occur and are associated with chalcopyrite in well developed crystals. Measurements on three isolated crystals yielded the following forms: a(100), o(111), v(731) and

Θ(19.1.1). The last is new to the species. The faces, with the exception of those of o(111), are sharp and brilliant. The planes of the new trapezohedron Θ(19.1.1) show a slight tendency to develop unsymmetrically in opposite pairs with respect to the axes of tetragonal symmetry. In several instances reddish violet spots of cubic outline were noted in the center of the hexoctahedral crystals. The following measurements served to identify the forms v(731) and Θ(19.1.1):

LETTER	ANGLE	NUMBER OF READINGS	MEASURED		CALCULATED	
			°	′	°	′
v : v.	731 : 713	4	20	39	21	13
v : v.	731 : 731	5	15	6	14	57
v : v.	731 : 371	4	42	53	43	12¾
a : Θ.	100 : 19.1.1	4	4	13	4	15

Magnetite

Split Rock, Essex co.

Among the specimens collected in the summer of 1907 by Prof. James F. Kemp of Columbia University, was one from the Split

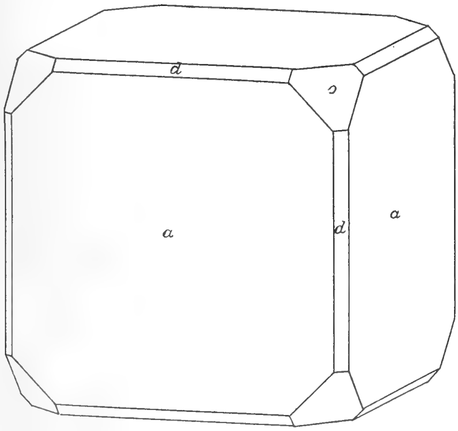


Fig. 3 Magnetite, Split Rock

Rock iron mine which proved to be of special interest. Through the courtesy of Professor Kemp this specimen has been placed at

the disposal of the writer for study. The specimen consists of a mass of titaniferous magnetite forming portion of a joint plane in the ore body. The surface of the joint is covered with small crystals of magnetite of cubic habit closely associated with wernerite in small transparent crystals. The comparative rarity of the cubic crystal habit in connection with magnetite[1] together with the adaptability of these crystals to measurement, has rendered advisable the following brief note:

The magnetite crystals which average 2 millimeters in diameter are exceptionally brilliant, well developed and free from distortion. The simpler combination which is shown in figure 3 consists of the cube a(100) developed to a dominant crystal habit and modified

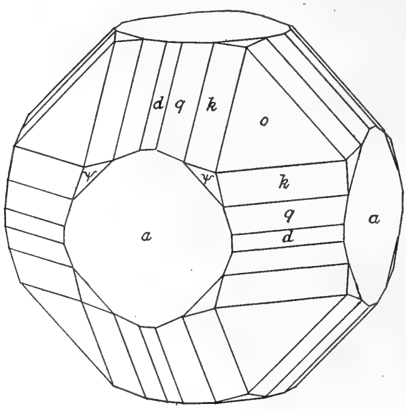


Fig. 4 Magnetite, Split Rock

by the octahedron o(111) and the dodecahedron d(110), both of these latter forms being present in small development. A more complex combination is shown in figure 4 and consists of the above forms developed to about equal habit and modified by the trigonal trisoctahedrons q(331) and k(552) and by the new trapezohedron $\psi = 707 = (711)$. They lie well in zone, the faces of the trigonal trisoctahedrons and of the dodecahedron being markedly striated parallel to the zone [100.110]. The planes of the trapezohedron $\psi(711)$ are small but extremely bright and give excellent reflections. The forms were identified from measurements obtained from five of the best crystals.

[1] Magnetite crystals of cubic habit were noted by H. Sjogren from Mossgrufva, Nordmark. Bul. Univ. Upsala. 1894–95. 2.63.

LETTER	ANGLE	NUMBER OF READINGS	MEASURED		CALCULATED	
			°	'	°	'
o : d.	111 : 101	12	35	19	35	16
o : q.	111 : 133	8	22	1½	22	0
o : k.	111 : 255	9	19	4	19	28
Ψ : Ψ'''. . .	711 : 7$\bar{1}$1	2	16	2	16	6
a : Ψ.	100 : 711	12	11	17	11	25½

Gypsum

Garbutt, Monroe co.

Among a number of specimens collected in the spring and summer of 1909 from the gypsum region of western New York by Mr Henry Leighton, assistant in economic geology, was a suite of 12 specimens of crystallized gypsum which furnished crystals comparatively rich in forms. The specimens in question were collected from the mine of the Garbutt Gypsum Co., and from No. 2 mine of the Lycoming Calcining Co., both situated at Garbutt, Monroe co. The gypsum crystals occur in narrow seams in massive gypsum and are sometimes associated with crystalline sulfur of remarkable purity and transparency. The crystals are colorless, transparent and average 5 millimeters in length parallel to the positive unit pyramid. In crystal habit, they conform closely to the type shown in figure 5. The prismatic zone is particularly rich in forms, yielding 8 of the 12 prisms recorded for gypsum.[1] Two rare negative pyramids in the zone [010.101] were noted, present either together or alternating on all 12 of the crystals measured. These

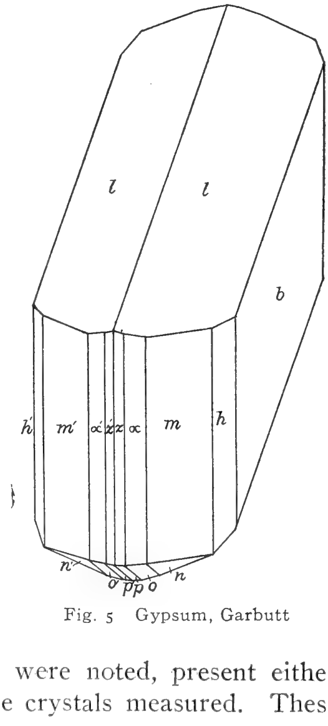


Fig. 5 Gypsum, Garbutt

[1] Goldschmidt, V. Krystallographische Winkeltabellen. Berlin 1897. Luedecke, O. Minerale des Harzes. Berlin 1896. 377.

gave goniometer readings which corresponded to the indexes ($\bar{2}12$) and ($\bar{3}13$). The letters o = ($\bar{2}12$) and p = ($\bar{3}13$) have been assigned to these forms. The distribution of the occurring forms is as follows:

LETTER	SYMBOL	CRYSTAL											
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
a.........	100	...	x	x	...	...	...	x	...	...	x	x	x
b.........	010	x	x	x	x	x	x	x	x	x	x	x	x
z.........	310	...	...	x	x	x	x	x	x	x	x	...	x
α.........	210	x	x	x	x	x	x	x	x	x	x	...	...
ψ.........	320	...	...	...	x	x	x	...	...	x	x	...	...
f.........	110	x	x	x	x	x	x	x	x	x	x	x	x
g.........	230	...	...	...	...	x	...	...	...	...	x	...	...
δ.........	350	...	...	...	x	...	...	...	...	...	...	...	...
h.........	120	x	x	...	x	x	x	...	x	x	x	...	...
k.........	130	...	...	...	...	x	x	...	x	...	x	...	...
l.........	111	x	x	x	x	x	x	x	x	x	x	x	x
n.........	$\bar{1}11$	x	x	x	x	x	x	x	x	x	x	x	x
o.........	$\bar{2}12$	x	x	...	...	x	x	x	x	x	x	...	...
p.........	$\bar{3}13$	x	...	x	x	x	...	x	...	x	x	x	x

The following measured angles served to identify the forms; the theoretical angles are calculated from the elements given by Beckenkamp[1] and adopted by Goldschmidt in his Krystallographische Winkeltabellen.

a : b : c = 0.4133 : 1 : 0.6895 $\beta = 98° \ 58'$

Summary of measured and calculated angles

LETTER	ANGLE	NUMBER OF READINGS	MEASURED		CALCULATED	
			°	′	°	′
b : a.....	101 : 100	5	90	½	90	0
b : z.....	101 : 310	10	77	11	77	12½
b : α.....	101 : 210	17	71	13	71	11½
b : ψ.....	101 : 320	5	65	41	65	35

[1] Zeitschr. f. Kryst. 1882. 6: 450.

Summary of measured and calculated angles—(*continued*).

LETTER	ANGLE	NUMBER OF READINGS	MEASURED		CALCULATED	
			°	′	°	′
b : f.	101 : 110	16	55	43	55	44½
b : g.	101 : 230	2	44	46½	44	23½
b : δ	101 : 350	2	41	53½	41	22½
b : h.	101 : 120	14	36	35	36	17
b : k.	101 : 130	4	26	3	26	5
b : l.	101 : 111	7	72	1	71	50
b : n.	101 : $\bar{1}11$	20	69	19½	69	20½
b : o.	101 : $\bar{2}12$	12	79	15½	79	19½
b : p.	101 : $\bar{3}13$	13	83	2	82	50
f : l.	110 : 111	4	49	12	49	16
f : n.	$\bar{1}10$: $\bar{1}11$	5	59	4	58	59
z : p.	$\bar{3}10$: $\bar{3}13$	5	64	58½	64	55

THE IROQUOIS AND THE STRUGGLE FOR AMERICA

ADDRESS BY ELIHU ROOT, SENATOR FROM NEW YORK, AT THE TERCENTENNIAL CELEBRATION OF THE DISCOVERY OF LAKE CHAMPLAIN.[1]

It is no ordinary event that we celebrate.

The beauty of this wonderful lake, first revealed to the eye of civilized man by the visit of Samuel de Champlain three hundred years ago; the powerful personality, noble character, and romantic career of the discoverer; the historic importance of this controlling line of strategic military communication, along which have passed in successive generations the armies whose conflicts were to determine the control and destinies of great empires; the value to Canada and to the United States of this natural pathway of commerce; the growth and prosperity of the noble states that have arisen on the opposing shores; their contributions to the wealth of mankind, to civil and religious liberty, to the world's progress in civilization — all these, withdraw the first coming of the white man to Lake Champlain from the dull and uninteresting level of the commonplace, while comparative antiquity, so attractive and inspiring to the people of the New World, lends dignity and romance to the figures and the acts that have escaped oblivion through centuries.

Even a dull imagination must be stirred as it dwells upon the influence which the events attending the discovery were to have, upon the issue of the great struggle between France and Great Britain for the control of the continent; the struggle between the two white races for the opportunity to colonize and expand, and between the two systems of law and civil polity, for the direction and development of civilization among the millions who were to people the vast region extending from the Atlantic to the Pacific and from the Rio Grande to the frozen limits of the north.

Authentic history records that late in June 1609 Champlain, accompanied by several white companions and by a great array of Algonquin Indians of the St Lawrence valley, left the French station on the site of the old Indian village of Stadacona, where now stands the city of Quebec, upon an expedition intended by the

[1] This illuminating address, publicly given before a distinguished audience, at Plattsburg, July 7, 1909, is here reprinted in order to give it as wide circulation as possible among the people of the State.

Indians for war and by the whites for exploration. They proceeded in canoes up the St Lawrence and turned south into the Richelieu, and in the early days of July after many vicissitudes and the desertion of the greater part of the Indians they dragged their canoes around the rapids of the river and came to the foot of the lake on whose shores we stand. They proceeded up the lake with all the precautions of Indian warfare in an enemy's country. As they approached the head of the lake they rested concealed by day and urged forward their canoes by night. At last, in this month of July three hundred years ago, they came upon a war party of the Iroquois. Both parties landed in the neighborhood of the present Ticonderoga and with the coming of the dawn joined battle. Protected by the light armor of the period Champlain advanced to the front in full view of the contending parties, and as the Iroquois drew their bows upon him he fired his arquebus. One of his white companions also fired. The Iroquois chief and several of his warriors fell killed or wounded, and the entire band amazed and terror stricken by their first experience with the inexplicable, miraculous and death-dealing power of firearms fled in dismay. They were pursued by the Algonquins, some were killed, some were taken prisoners, and the remainder returned to their homes to spread through all the tribes of the Iroquois the story that a new enemy had arisen bringing unheard of and supernatural powers to the aid of their traditional Algonquin foes. The shot from Champlain's arquebus had determined the part that was to be played in the approaching conflict by the most powerful military force among the Indians of North America. It had made the confederacy of the Iroquois and all its nations and dependencies the implacable enemies of the French and the fast friends of the English for all the long struggle that was to come.

A century or more before the white settlement five Indian nations of the same stock and language under the leadership of extraordinary political genius had formed a confederacy for the preservation of internal peace and for common defense against external attack. Their territories extended in 1609 from the St Lawrence to the Susquehanna; from Lake Champlain and the Hudson to the Genesee, and a few years later to the Niagara. There dwelt side by side the Mohawks, the Oneidas, the Onondagas, the Cayugas and the Senecas in the firm union of Ho-de-no-sau-nee — the Long House of the Iroquois.

The Algonquin tribes that surrounded them were still in the lowest stage of industrial life and for their food added to the

spoils of the chase only wild fruits and roots. The Iroquois had passed into the agricultural stage. They had settled habitations and cultivated fields. They had extensive orchards of the apple, made sugar from the maple and raised corn and beans and squash and pumpkins. The surrounding tribes had only the rudimentary political institution of chief and followers. The Iroquois had a carefully devised constitution well adapted to secure confederate authority in matters of common interest, and local authority in matters of local interest.

Each nation was divided into tribes, the Wolf tribe, the Bear tribe, the Turtle tribe, etc. The same tribes ran through all the nations, the section in each nation being bound by ties of consanguinity to the sections of the same tribe in the other nations. Thus a Seneca Wolf was brother to every Mohawk Wolf, a Seneca Bear to every Mohawk Bear. The arrangement was like that of our college societies with chapters in different colleges. So there were bonds of tribal union running across the lines of national union, and the whole structure was firmly knit together as by the warp and woof of a textile fabric.

The government was vested in a council of fifty sachems, a fixed number coming from each nation. The sachems from each nation came in fixed proportions from specific tribes in that nation; the office was hereditary in the tribe; and the member of the tribe to fill it was elected by the tribe. The sachems of each nation governed their own nation in all local affairs. Below the sachems were elected chiefs on the military side and Keepers of the Faith on the religious side. Crime was exceedingly rare; insubordination was unknown; courage, fortitude and devotion to the common good were universal.

The territory of the Long House covered the watershed between the St Lawrence basin and the Atlantic. From it the waters ran into the St Lawrence, the Hudson, the Delaware, the Susquehanna and the Ohio. Down these lines of communication the war parties of the confederacy passed, beating back or overwhelming their enemies until they had become overlords of a vast region extending far into New England, the Carolinas, the valley of the Mississippi and to the coast of Lake Huron.

They held in subjection an area including the present states of New York, New Jersey, Pennsylvania, Delaware, Maryland, Ohio, Kentucky, West Virginia, Northern Virginia and Tennessee, and parts of New England, Illinois, Indiana, Michigan and Ontario. Of all the inhabitants of the New World they were the most terrible

foes and the most capable of organized and sustained warfare, and of all the inhabitants north of Mexico they were the most civilized and intelligent.

The century which followed the voyages of Columbus had been for the northern continent a period of exploration and discovery, of search for gold and for fabulous cities and for a passage to the Indies, of fugitive fur trade with the natives, of fisheries on the banks and of feeble, disastrous attempts at occupation, but not of permanent settlement. Ponce de Leon and De Soto and Verazzano, Cartier and the Cabots and Drake and Frobisher and Gilbert and Gosnold, had brought the western coast of the Atlantic out from the mists of fable, but they had left no trace upon its shores. Jean Ribaut and his French Huguenots had attempted to do for their religion in Florida what the Pilgrims did in the following century on the coast of Massachusetts, but their colony was destroyed with incredible cruelty in the name of religion by the ferocious Spaniard, Menendez, and the colony of Menendez was in turn destroyed by the Gascon de Gourgues, save a feeble remnant on the site of St Augustine. Raleigh with noble constancy and persistency had wasted his fortune in repeated and vain attempts to establish a colony in Virginia. On the sites of the modern Quebec and Montreal, at Tadousac, at the mouth of the St Croix and at Port Royal, Jacques Cartier and Roberval, Pontgravé and De Monts, Poutrincourt and Lescarbot had seen their heroic and devoted efforts to establish a new France brought to naught by cold and starvation and disease. In that month of July 1609 in all the vast expanse between Florida and Labrador no settlement of white men held its place or presaged the coming of the future multitude save at Jamestown behind the Capes of Virginia, where Christopher Newport's handful of colonists had barely survived two years of privation, and at Quebec, where the undaunted Pontgravé and Champlain only one year before had again gained a foothold. At Jamestown the mournful record of the winter of 1609 to 1610 shows us that in the spring but sixty of the colonists were living. At Quebec twenty-eight Frenchmen with Champlain had braved the rigors of a Canadian winter, and in the spring of 1609 but eight remained alive.

In this same month July 1609 the Half Moon of Henry Hudson was repairing damages in Penobscot bay after her voyage across the Atlantic, and preparing to sail on to the noble river that still bears her commander's name.

The field was open; the hands upon the margin that reached out

to grasp control seemed few and feeble, but the period of preparation was past. The mighty forces that were to urge on the most stupendous movement of mankind in human history had already received their direction. The time was ripe for the real conflict to begin, and it had its momentous beginning when the chief of the Mohawks fell before the arquebus of Champlain at Ticonderoga.

The conditions which limited the powers and directed the purposes of the various countries of Europe in the early years of the seventeenth century made it inevitable that the struggle for American control should ultimately become a single combat between France and Great Britain.

It is true that Spain had overturned the tribal government of the Aztecs and held possession along the northern shores of the Gulf of Mexico, a vantage ground from which she might well have pressed to the northward successful plans of occupation. But Spain had no such plans. When the search for treasure had failed, and it was plain that no more Perus and Mexicos were to be found, the dark forests of the north Atlantic offered no attractions to the Spanish Conquistadores who sought the spoils of conquest rather than the rewards of labor.

With the death of Philip the Second the decline of Spanish power had already begun. His successors were feeble and incapable. The stern, repressive and despotic control over body and soul effected by the union of military and religious organization during the first century of United Spain was accompanied by a marvelous efficiency and energy that made Spain for a time the foremost maritime and colonizing power of the world. The price of that efficiency, however, was the loss of the only permanent source of national energy, the independence and free initiative of individual character among her citizens. Thenceforth Spain was no longer to sway the rod of empire, but holding it weakly in feeble hands was to lose one by one the world-wide possessions of Charles the Fifth and Philip the Second, until the time when the penalty of her national sin against civil and religious freedom should have been paid and the native strength and nobility of her character should be able to reassert themselves in a period of renewed growth and reestablished power and prosperity; a time which we hope and trust has already come.

Portugal, still clinging to the fruits of her explorers' genius, and sturdy Holland, strong in her newly won freedom, were looking not to North America but to Brazil and to the Orient for their opportunities to expand, and the future colony of New Amsterdam

was destined to be readily transferred to the English for the sake of greater opportunities to the Dutch East India Company.

Germany was not yet a maritime power. Loosely compacted under the failing hegemony of the House of Austria she was upon the threshold of the Thirty Years' War, in which the most frightful slaughter and devastation were to destroy her cities, lay waste her fields, reduce her population from thirty millions to twelve millions, and set back her civilization for centuries.

Into that vortex of destruction Sweden also was about to be drawn, and her forces were to be engrossed in the struggle for national existence, so that the hopes of Gustavus Adolphus for a New Sweden upon the banks of the Delaware were to fail of fruition, and the Swedish colony in America was to pass with hardly a struggle into the hands first of the Dutch and then of the English.

Prussia was a dependent dukedom. Russia had still three quarters of a century to wait before Peter the Great was to begin to lead her from semibarbarism into the ranks of civilized powers. Italy was a geographical expression covering a multitude of petty states.

Of all the peoples of Europe, only the French and the English possessed the power, the energy, the adventurous courage, the opportunity and the occasion for expansion across the Atlantic. The field and the prize were for them and for them alone.

Upon the throne of France was Henry the Fourth, the greatest of French kings. In the governing class of Frenchmen, political and religious, were the virile strength, the intellectual acumen, the romantic chivalry, the strong passions, the love of glory, the capacity for devotion to ideals, which were to make possible the rule of Richelieu, the ascendancy of Louis the Fourteenth, the political idealists of the Eighteenth century, the tremendous social forces whose outbreak in the French Revolution appalled the world, and the armies of Napoleon.

In England the reign of great Elizabeth had just closed. It was the England of Spenser and Shakspere and Bacon; of Cecil and Raleigh; of Drake and Frobisher. John Hampden and Cromwell and Milton were in their childhood. For four centuries since Magna Charta, Englishmen had become accustomed to the assertion of the individual rights of the citizen against arbitrary power. Since the repudiation of Roman supremacy over the national church by Henry the Eighth three generations had become wonted to the assertion of religious freedom. King James's translation of the

Bible was in progress and nearly completed. The deep religious feeling of the Puritan reaction against both Roman and royal episcopacy that was to cost Charles the First his life and James the Second his throne had already become a controlling motive among a great multitude of the English people.

From these two countries, each possessed of great powers, each endowed with noble qualities, proceeded the colonists who were to dispute for the possession of America. The French movement was in the main governmental, aristocratic, proceeding from state and church, designed to extend and increase the power, dominion, and glory of the king, to convert the Indians to the true faith, and to extend over them and over all the lands through which they roamed, and over all who should come after them and take their place, the same iron rule of conformity against which the Huguenots of France were vainly contending. The English movement was in the main popular, proceeding from the people of England who wished to escape either church or state at home and to find freedom in a new world for the practice of their religion or the pursuit of their fortunes according to their own ideas. Some of the English colonies braved the hardships of exile rather than conform against their consciences to requirements of practice and doctrine which the English church imposed. Some sought for fortune in the New World because the state had so distributed the property and so closed the avenues for advancement in England that they must needs seek opportunities elsewhere if at all.

For centuries the struggle between civil and religious absolutism on the one hand and individual liberty on the other were waged alike in France and England. The attempt to colonize America came from one side of the controversy in France and from the other side of the same controversy in England. The virtues of the two systems were to be tried out and the irrepressible conflict between them was to be continued in the wilderness.

For capable and efficient leadership, for farsighted and comprehensive plans, for clear understanding of existing conditions and prevision as to the future, for conspicuous examples of heroic achievement and self-devotion, the palm must be awarded to the French over their English competitors. There are few chapters in history so full of romantic interest, so compelling in their demands for sympathy and admiration, as the record of the century and a half that began with the wooden fortress of Champlain under the bluff at Quebec and ended with the fall of Montcalm on the Heights of Abraham.

The world owes many debts to France. Not the least of these is the inspiration the men of every race can find in the noble examples of such explorers as Niccolet and Joliet and La Salle; such leaders as Champlain and Frontenac and Duquesne and Montcalm; and such missionaries as Le Caron and Breboeuf and Marquette. They strove for the execution of a great design, holding hardship and suffering and life of little account in their loyalty to their religion and their king. With infinite pains they won the friendship of the Indians of the St Lawrence and the far Northwest; they carried the flag of France to the mouth of the Mississippi; they drew a cordon of military posts up the St Lawrence across to the Mississippi and down to the Gulf, well designed to bar the westward advance of the English colonies, to save the great West for their race and thence to press the English backward to the sea. Their soldiers were, as a rule, better led, better organized, and moved on more definite and certain plans than the English. Occasionally some born fighter on the English side would accomplish a great deed, like Pepperell at Louisburg, or some man of supreme good sense would bring order out of confusion, as did Franklin and Washington, but as a rule colonial legislatures were slow and vacillating, colonial governors were indifferent and shortsighted, and colonial movements were marked by a lack of that definite responsibility, coupled with power, so essential to successful warfare.

Fortunately for England, between the two parties all along the controlling strategic line from this Lake Champlain to the gateway of the West at Fort Duquesne, stretched the barrier of the Long House and its tributary nations. They were always ready, always organized, always watchful. They continually threatened and frequently broke the great French military line of communication. Along the whole line they kept the French continually in jeopardy. Before the barrier the French built forts and trained soldiers — behind it the English cleared the forests and built homes and cultivated fields and grew to a great multitude, strong in individual freedom and in the practice of self-government. Again and again the French hurled their forces against the Long House, but always with little practical advantage. At one time De Tracy, the Viceroy, burned villages and laid waste the land of the Iroquois with twelve hundred French soldiers. At another De La Barre, the Governor, with eighteen hundred; at another De Nonville with two thousand; at another Frontenac with six hundred; at still another, Frontenac

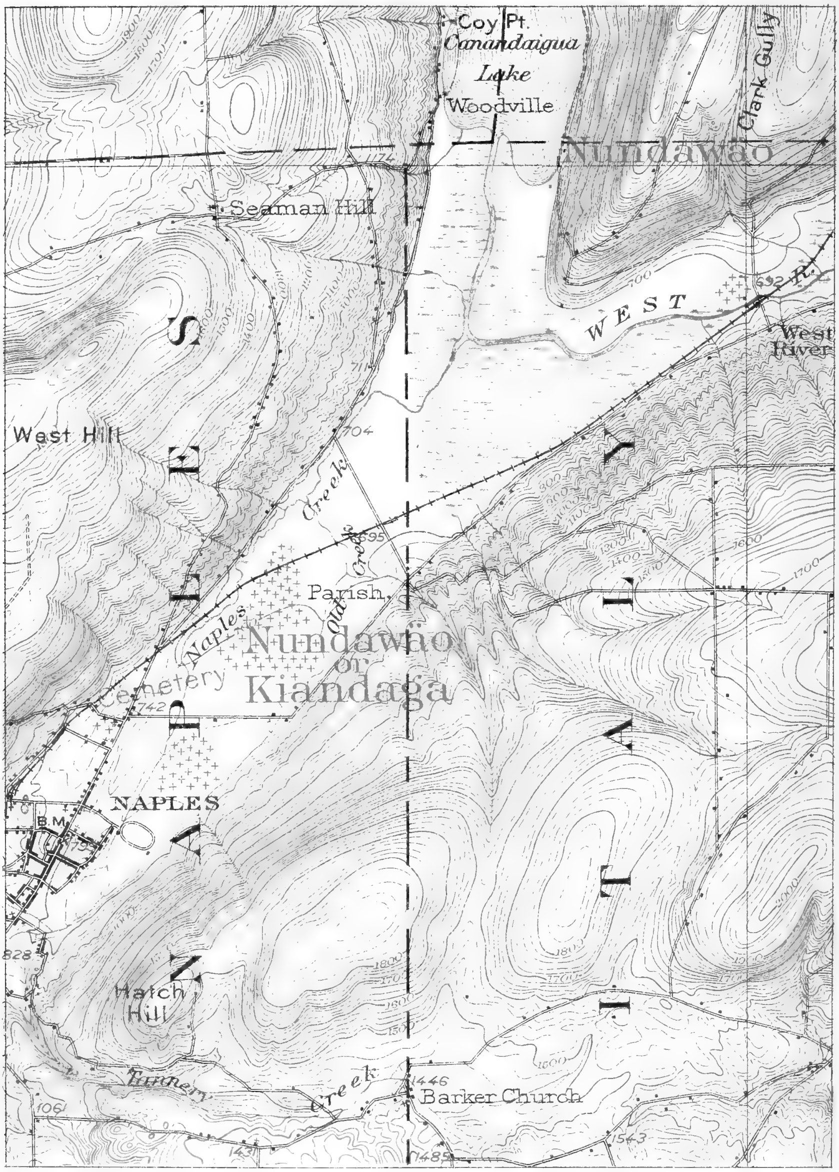
with a thousand. Always there came also a cloud of Algonquin allies. Always the Iroquois retired and then returned, rebuilt their villages, replanted their fields, resumed their operations and in their turn took ample revenge for their injuries.

So, to and fro the war parties went, harrying and burning and killing, but always the barrier stood, and always with its aid the English colonies labored and fought and grew strong. When the final struggle came between the armies of France and England, the French had the genius of Montcalm and soldiers as brave as ever drew sword; but behind Wolfe and his stout English hearts was a new people, rich in supplies, trained in warfare and ready to fight for their homes. South Carolina, the records show, furnished twelve hundred and fifty men for the war; Virginia, two thousand; Pennsylvania, two thousand seven hundred; New Jersey, one thousand; New York, two thousand six hundred and eighty; New Hampshire and Rhode Island, one thousand; Connecticut, five thousand; Massachusetts, seven thousand. It was not merely the army — it was that a nation had arrived, too great in numbers, in extent of territory, in strength of independent, individual character, to be overwhelmed by any power that France could possibly produce. The conclusion was foregone. A battle lost or won at Quebec or elsewhere could but hasten or retard the result a little. The result was sure to come as it did come.

In all this interesting and romantic story may be seen two great proximate causes of the French failure and the English success; two reasons why from Quebec to the Pacific we speak English, follow the course of the common law, and estimate and maintain our rights according to the principles of English freedom.

One of these was the great inferiority of the Indian allies of the French, and the great superiority of the Indian allies of the English; the effective and enduring organization, the warlike powers, of the Iroquois, and their fidelity to the "covenant chain" which bound them to our fathers. The other cause lies deeper: It is that peoples, not monarchs, settlers, not soldiers, build empires; that the spirit of absolutism in a royal court is a less vital principle than the spirit of liberty in a nation.

In these memorial days let there be honor to Champlain and the chivalry of France; honor to the strong free hearts of the common people of England; and honor also to the savage virtues, the courage and loyal friendship of the Long House of the Iroqouis.



THE INDIAN VILLAGE NUNDAWÄO

NUN-DA-WÄ'-O, THE OLDEST SENECA VILLAGE

BY D. D. LUTHER

Ge-nun-de-wa, or Bare hill, on the east side of Canandaigua lake 5 miles from the head, is the legendary birthplace of the Seneca nation, the place where the Nun-dá-wä-o-nó or "Great Hill people" of the Iroquois Indians held their first council fire. Its summit is 865 feet above the lake.

At the south is Vine valley, separating it from a larger hill that rises 1200 feet from the lake with a steep acclivity and extends into the swamp half a mile beyond the head.

This larger hill is 4 miles long and 3 miles broad at the base, the deep valley of West river lying on the east side.

Though its summit is not the highest in this region, its configuration and surroundings make it, perhaps, the most prominent feature in the topography of the Canandaigua lake valley and its name Nun-da-wä'-o (Great Hill) strikingly appropriate. Canandaigua lake extends in a southwesterly direction about 6 miles beyond the present head of the lake.

For 2 miles from the head the bottom of the valley is a sparsely timbered, flaggy swamp through which flows Naples creek, the principal inlet of the lake, a deep sluggish stream 30 to 50 feet wide, navigable for rowboats for about 2 miles.

Next south of the swamp lie the "flats," an alluvial plain nearly a mile wide at the north end but coming to a point at the foot of Hatch hill directly opposite the village of Naples. Here the Naples creek leaves the base of the hill and takes its course diagonally across the valley for 1⅛ miles, thence northward along the foot of West hill to the swamp. A smaller stream takes the drainage from Hatch hill and flows along the east side of the valley for 1½ miles, then, after joining the Parrish gully stream crosses the flat to the main inlet not far from the south edge of the swamp, the two streams thus nearly inclosing an area of rather more than a square mile of land.

Indian relics are common on a large part of this area, and in two localities their abundance and character are evidences of long or repeated occupation as the site of a village of considerable size.

Conditions were exceedingly favorable for the Indians mode of life here. Except the continuation of the valley to the lake at

the north and the West river valley at the northeast, the flats are entirely surrounded by great hills, Hatch hill at the east, Knapp hill and Pine hill at the south, and High point, West hill and Gannett hill on the west are all 1300 to 1500 feet higher than the bottom of the valley, while passes between them at the hight of about 700 feet make neighboring valleys accessible.

The villages were not only sheltered from the winter storms by these hills; they were also so secluded that, though in the heart of the Seneca country and on the principal trail leading from Kanadesaga to the Cohocton and Canaseraga valleys, neither De Nonville's invasion of their territory in 1687 nor Sullivan's punitive raid in 1779 reached them.

The slopes of the hills, cut by numerous gullies and large ravines, and the swamp must have afforded game in abundance. The lake was easily reached by canoe down the inlet or along the foot of West hill, while nuts and berries and the sugar maple trees grew everywhere.

The soil, a dark mellow, rich alluvium, required but little cultivation to produce large crops of fruit, corn and vegetables, and several large springs furnished an ample supply of pure water.

Little can be ascertained in regard to the Indian occupation of this valley previous to the advent of the white settlers. On Pouchot's map of 1758 the number 28 indicates a village here with the name *Kanentage*. Dr Beauchamp says this means "Canandaigua, but at the wrong end of the lake." The dotted line showing Pouchot's route, however, passes through this valley [*see* N. Y. State Mus. Bul. 78].

Lewis H. Morgan in *The League of the Iroquois* 1851, describes the separation of the Iroquois into the Five Nations and says [page 6, Dodd, Mead & Co. 1904]: "The Cayugas and Senecas were many years united and resided upon the Seneca river, but one band of them having located upon the east bank of Cayuga lake grew up in time to a distinct nation; while the residue, penetrating into the interior of western New York, finally settled at *Nun-da-wä'-o* at the head of Canandaigua lake and there formed the nucleus of the Seneca nation. The Onondagas have a legend that they sprang out of the ground on the banks of the Oswego river; and the Senecas have a similar legend that they sprang out of the ground at Nun-da-wä'-o." On page 48 he says: "The Senecas called themselves the Nun-da'-wä-o-no' which signifies 'the great hill people.' Nun'-da-wä, the radix of the word, means 'a

great hill' and the terminal syllables 'o-no' convey the idea of 'people.' This was the name of their oldest village, situated upon a hill at the head of Canandaigua lake near Naples where, according to the Seneca legend, they sprang out of the ground." On the map accompanying the book, the site of the village of Nun-da-wä'-o is located precisely on that part of the Naples flats where evidences of the former existence of an Indian village are now found in greatest profusion.

Though flints are occasionally found on the hillsides, and very rarely a pestle, nothing to indicate an Indian village has yet been discovered in the region about the head of Canandaigua lake except in the valleys.

The late Miss Jane Mills, who during many years collected material for a history of Naples, getting much of her data from descendants of the pioneer settlers, says in her unpublished manuscript: "they (the first comers) arrived at the village of Nun-da-wä'-o."

French's *Gazetteer* of New York, page 407, note, says: "Naples was called by the Indians Nun-da-wä-o."

There is not much room for doubt that the village on the flats was the traditional Nun-da-wä-o, but it was not unusual for Indian villages to have two or more names, and we find that the pioneers and their descendants have preserved another name for this one. This valley was in the central part of the Phelps and Gorham Purchase of 1787, the Indian title to which was extinguished in 1788. In 1789 the present township of Naples was sold to a company of Massachusetts men and surveyed by a party of six men from that state. So far as can be ascertained these were the first white men, except Pouchot, who arrived at this Indian village.

In an address before the Naples Lyceum in 1831 the speaker, whose name is not known but who claimed to have derived his information from one of these surveyors, said: "They entered the inlet that flows through this valley and came on shore at the old Indian landing 2 miles below the village of Naples. Here they found an Indian settlement which in the dialect of the natives was called Ki-an-da-ga, said to mean 'between the hills.' There resided here at this time 30 to 40 families embracing about 100 souls and from the contiguity of ancient fortifications[1] it may be presumed that these natives had been lords of the soil from time immemorial."

[1] Nothing more is known of fortifications here.

The late Seymour H. Sutton of Naples published in 1851 a series of articles entitled the *Annals of Naples* in which he states that the first party of settlers came up the lake on the ice in February 1790 and "moved up the inlet till they arrived at a wigwam where they sought the hospitality of the Indian owner, while the cattle were turned out to feed on the tall dry grass that grew in the valley of Koyendaga.

On the succeeding morning they saw the smoke of 40 wigwams against the sky and the Indians began to assemble in small groups to view the white intruders. *Hiotonta* in the native dignity of a chief of gigantic stature and graceful manners, and *Canesque* (Ka-nes-ka?) the tall and venerable ex-chief of a hundred winters, also comes to look.

'The lofty hills,' says Parrish (one of the first settlers) 'on either side of *Koyendaga* were so destitute of timber that a deer might plainly be seen from one extreme end to the other, even to the very top.'

At this time the Indians cultivated a large portion of the land along the creek. The flats were interspersed with patches of wild plum and the dry land sparsely covered with black walnut and sugar maple trees."

Although the Indians had surrendered all claim to the land, they had reserved the right to hunt and fish here for 20 years, and many of them remained and appear to have lived on the most amicable terms with the settlers.

Even after they had removed to the reservation on the Genesee river, they returned annually during the hunting season. The late Col. N. W. Clark could remember seeing their group of wigwams near where the Methodist church now stands in Naples village. They assisted the first settlers in their construction of a hominy block or stump mortar, the pestle or pounder of which was operated by aid of a spring pole, and took their turn in the use of it.

Sutton relates some later incidents connected with the Indians here: "They were in the habit of visiting Squakie hill near the Genesee river. Canesque was there and, dying of old age, he desired to be brought back to *Koyendaga* to die and be buried with those he loved. In the winter of 1794 two Indians, from sympathy and kindness, conveyed the aged chief on a sled over 40 miles to the place where he chose to die. The whites administered to his comfort till he died. . . His funeral was

the first attended here by the settlers." The place of his burial is not known. "In the fall of 1796 several young Indians joined the settlers in a panther hunt in a large ravine south of the settlement, now known as 'Tannery gully.'

The winter of 1797–98 was uncommon for the depth of snow. The Indians could not hunt even with snowshoes and were reduced to the verge of starvation and were frequently supplied with provisions by the settlers. On a certain day the Indians assembled at a point now in the southern part of the village of Naples and after a basswood tree had been cut down the tall chief *On-is-o-ti-ka* mounted the stump. The Indians silently surrounding the chief with their rifles pointing up as in an act of presentation, remained in silence while the chief addressed them with an eloquence and dignity of manner which seemed to impress them and arouse their feelings. At the close of this speech the report of the rifles told the end of the conference and the Indians quietly departed to their homes.

In the autumn of 1798 the Indians held a grand festival on the higher ground a mile southwest of their larger village, having assembled from a great distance, all dressed in their neatest manner. A large fire had been built the night before. The Indians stood in small groups. The squaws were sitting quietly on the ground, the little papooses lashed to the board were set up against the trees. At a given signal the Indians joined hands in one grand circulade (*sic*) and danced around the fire, rattling small sticks, beating small drums and singing in a loud monotonous tone, giving great emphasis to the last word of each strain. The squaws were in their best attire, with fur hats with silver bands and with numerous bells and hawks' claws, beads and shells hanging from their blankets. The Indians had many gaudy trinkets and trappings peculiar to their taste and their clinking sound seemed to harmonize with their wild music. The chief Onisotika presided."

At the time Mr Sutton wrote the *Annals* there were living in the vicinity several sons and daughters of the pioneers and it was from them that he derived his information.

In a centennial address delivered in 1889 by Hon. E. B. Pottle, grandson of one of the first settlers, he described their journey over the ice on the lake and up the inlet "until, as they in after years said, they reached the lower Indian village. This was on what is now my farm, the upper Indian village being south of the road across the flats on lands now owned by Ira C. Williams."

The localities specified are approximately those where relics have recently been found in greatest profusion.

The lower village which apparently was much the larger, was not situated directly upon the banks of the inlet but mainly along the east side of the outlet of a large spring now known as the "Barber spring" and extending east and south to the vicinity of other springs.

The upper village was about ¾ mile further south and bounded on the east by the "old creek" but appears not to have extended to the Naples creek on the west. All except about 1 acre of this site is covered by a heavy turf and its full extent is not known.

Evidences of occupation have also been found on the east side of the "old creek" and on the north side of the alluvial cone at the mouth of Parrish gully and west of Naples creek on the higher ground in the vicinity of the old cemetery.

If any place was specially set apart by the Indians as a burying ground the locality is not certainly known though it is traditional that the old cemetery in the northern part of the village of Naples was an "Indian burying ground" before the whites appropriated it.

Skeletons supposed to be those of Indians have been exhumed near Academy street and one of a man buried in a sitting posture and facing toward the east was found in 1907 in "Woodchuck knoll" a little south of the upper Indian village. No relics have been found in graves here.

The former existence of "an Indian village on the flats" has been pretty generally known to Naples people, but it has never been an object of special attention or interest until recently the writer has undertaken to ascertain, as nearly as possible, the precise location of the two villages as shown by the distribution of the relics and to collect whatever might be found that bore clear evidence of having been fashioned or used by those who dwelt in them.

When it is remembered that the inhabitants were not driven away from their homes hurriedly but had abundant time in which to remove whatever they considered of value; that the land has been under more or less vigorous cultivation by the whites for 120 years, and that less than ⅕ of the area can now be satisfactorily searched, the remaining 4/5 being covered by heavy turf, the quantity of the material collected, if not the quality, is of some interest.

The material consists of stone mortars or anvils, pitted hammer stones, pestles, sinkers, hoes, celts, arrows and other flint articles, pottery in fragments and stems of pipes, etc.

Mortars or anvils. These are blocks of gray sandstone from the local Portage flags, roughly dressed to a nearly circular shape 8 to 12 inches in diameter and about 2 inches thick, weighing 7 to 15 pounds. On one side a shallow cup-shaped depression has been picked out by hard blows with a sharp instrument, leaving a rough surface. The other side is usually slightly concave and smoothly polished, probably by use of a muller in pulverizing substances very finely. 21 of these were found, 18 in the vicinity of the lower site, one at the upper, one half a mile east of the lower site and one half a mile southwest. Many broken fragments occur.

Hammer stones. These are mostly round or oval flattened drift pebbles from the nearby creek bed weighing 1 to 4 pounds. Over 200 of these were found, 145 at or near the lower site, 54 at the upper, one half a mile east and another half a mile southwest of the lower site; 33 of these show by the battered condition of their ends and sides that they have been used as veritable hammers against some hard substance, possibly to pulverize the rock mixed with clay in the process of manufacturing pottery. 18 are granite or schist, the others being of hard quartzite or sandstone. The pits on these are large, shallow in proportion to size and worked smooth. The pits aid very much in getting a firm and easy grasp of the implement. 4 are flat blocks of sandstone 1½ to 2 inches thick and have a funnel-shaped pit on one side only an inch in diameter and ½ inch deep. The pit on one block shows that it was made by a rotary drill. The other specimens are all sandstone, mostly Portage or Medina, and in shape range from globular to irregularly angular. The pits also show a variety of shapes, some being large and worked out smoothly at the expense of considerable labor, the other extreme being those made by a half dozen hard blows with a sharp pick. 5 have two pits on one side.

While the most of these pitted stones would be serviceable in cracking nuts, grinding corn and similar substances, some of them are not at all suitable and evidently were not designed for such use.

Pestles. One 24½ inches long, very roughly dressed. One 14 inches long, flattened and slightly curved; one 12 inches long, 1 ½

inches in diameter, very symmetrical and polished; one 6 inches long, very crude, and fragments of 9 others, were obtained.

Sinkers. These embrace 71 flat pebbles of sandstone 2 to 4 inches in diameter and ¼ to ⅜ inches thick with two notches opposite each other on the edge.

Hoes etc. 22 thin pieces of sandstone 3 to 6 inches across and ½ to ¾ inches thick with the edges on one or more sides chipped thin, were found. Some of these were doubtless hoes, others may have served as axes.

Pottery. Fragments of clay vessels are very abundant at the lower site where the subsoil is a fine plastic clay quite suitable for the potter's use. 350 fragments 1 to 3 inches across and ⅛ to ½ inch thick were collected, all of which show surface ornamentation and 30 or more of them that of the rims. Pottery fragments are very rare at the upper site.

Parts of 9 pipe stems and of two bowls, one of the latter of stone, the others of clay, were found.

Flints. Those found on the sites consist of 26 arrow points entire, 20 nearly so and 20 others much broken, or spoiled in making. Also 4 perforators or drills, all with points broken off. A small curved knife, a small gouge, and a quart of chips or flakes. These are very abundant.

The arrows are all small and triangular in shape. Except one, which is translucent white quartz, they are common dark to light chert, such as occurs in layers and nodules in the Onondaga limestone. The only flint article found on the sites that has a stem is one of the perforators, though many stemmed arrows and spears have been found on the higher ground south of the sites, specially in the vicinity of a large spring near the railroad station in Naples and another half a mile south of the village.

Besides the above named articles there were found 2 celts, 2 stone balls, 3 stone disks and a few others that show artificial shaping for some unknown purposes.

Mortars, pitted stones, sinkers and flints similar to those above described were found on a small site near the West river bridge, 3 miles northeast from the village on the flats, where the first white settlers in 1797 found an Indian village composed of a few wigwams.

Like that of all the New York Indian nations, the early history of the Senecas is buried under legends that, although apparently purely mythical, may be not only allegorical but traditional as well and containing germs of real history.

The several versions of the legend concerning the origin of this nation all agree in locating this event in the region about the south end of Canandaigua lake.

To those who are acquainted with the topography of this region it would not be an overtax on credulity to believe that a band of Indians wishing or compelled to emigrate from their home on the Seneca river, and finding their way toward the west barred, possibly by hostile tribes, should take their course toward the southwest, through the West river valley and on arriving at this rich and spacious but sheltered and secluded intervale among the great hills, should actually make their first settlement and form their first village here.

And it is entirely reasonable to believe that, dwelling here in peace and plenty, their numbers would increase as the years passed, until having extended their occupancy down the lake shores and into the many warm valleys among the hills, the chief men among them should assemble on beautiful Genundewa, light their first council fire and bring into life a new nation with the significant and appropriate name Nun-da-wä-o-no, the People of the Great Hills.

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Education Department Bulletin

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No. 463 ALBANY, N. Y. JANUARY 15, 1910

New York State Museum

JOHN M. CLARKE, Director

Museum bulletin 135

GEOLOGY OF THE PORT LEYDEN QUADRANGLE, LEWIS COUNTY, N. Y.

BY

W. J. MILLER

New York State Education Department

Science Division, September 24, 1909

Hon. Andrew S. Draper LL.D.

Commissioner of Education

SIR: I have the honor to transmit herewith for publication as a bulletin of the State Museum, the manuscript of a report on the *Geology of the Port Leyden Quadrangle, Lewis county,* prepared by Prof. W. J. Miller, a member of the staff of this division.

Very respectfully

JOHN M. CLARKE

Director

State of New York
Education Department
COMMISSIONER'S ROOM

Approved for publication this 24th day of September 1909

A. S. Draper

Commissioner of Education

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GEOLOGY OF THE PORT LEYDEN QUADRANGLE, LEWIS COUNTY, N. Y.

BY

W. J. MILLER

INTRODUCTION

The Port Leyden, New York, quadrangle of the United States Geological Survey comprises the region lying along the western border of the Adirondack mountains and is included between latitude lines 43° 30′ and 43° 45′ north and between longitude lines 75° 15′ and 75° 30′ west. The map covers 1/16 square degree or about 215 square miles of territory, all of which lies in Lewis county except a few square miles extending into Oneida county at the extreme southeast. The Rome, Watertown and Ogdensburg Division of the New York Central Railroad traverses the region from north to south through the Black river valley. Port Leyden, Lyons Falls, Glenfield, Martinsburg, Turin and Constableville are the principal villages.

This region, like most others along the border of the Adirondacks, was at one time a dense forest which has nearly all been cut away, leaving only small wooded areas of second growth. Next to agriculture, the chief industry is the manufacture of wood pulp and paper, the largest mills being located at Lyons Falls, Goulds Mill, Kosterville, Shuetown, Lyonsdale and Port Leyden. The logs used are driven down Moose river. A number of small sawmills are still in operation.

On the east side of Black river the soil is nearly always sandy and rather unproductive, while on the west side of the river the soil is usually rich and supports a prosperous farming community. The principal products are milk and cheese.

GENERAL GEOLOGIC FEATURES

Under this heading it is proposed to briefly outline the geologic history of the whole Adirondack region so that the detailed study presented in this report may be made more intelligible to the reader. This outline is based largely upon the admirable treatises of Prof. H. P. Cushing.

So far as known the oldest rocks of the Adirondacks are those of Grenville (Precambric) age. They are sedimentary rocks, originally shales, sandstones and limestones, which have been highly metamorphosed into gneisses and crystalline limestone. These rocks are of unknown but great thickness, and are widely scattered throughout the Adirondacks, thus showing that the whole region was under water at the time of their deposition.

After the deposition of the Grenville sediments the region was raised above the ocean level and the rocks began to decompose and suffer erosion. Either just before, during, or after the uplift, great masses of igneous rocks were intruded. The Grenville rocks were for the most part engulfed by the intrusion so that only occasional patches of them were left intact.

After the igneous activity the rocks became thoroughly metamorphosed by being squeezed, highly folded and converted into gneisses. Such changes can take place only at great depths (several thousand feet) and hence we are led to the belief that a vast erosion of the original land masses must have taken place. This in turn signifies that the land masses must have remained above sea level for an immense length of time.

At or toward the close of this long period of erosion, igneous activity of a minor character took place. The basic igneous rocks erupted at this time are especially well shown in the northeastern Adirondacks, where they were squeezed up between joint planes in the older rocks. That these rocks are much younger than the igneous rocks first mentioned is clearly shown by their mode of occurrence and their general lack of metamorphism.

Toward the close of the erosion period the region of the Adirondacks was nearer the sea level and of slighter relief than at present. Then the whole region began to sink slowly, allowing the sea to encroach upon the land until only an island was left or probably even until the whole region was under water. During the subsidence, deposition of Paleozoic sediments went

on, one layer above another, the younger deposits overlapping each other and encroaching upon the sinking land surface. Since the subsidence was not entirely uniform on all sides certain local variations in deposition occurred.

The first of the deposits to form upon the sinking floor was the Potsdam (Cambric) sandstone now found exposed nearly everywhere except along the southwest border. After this the sediments changed in character and the limestones of the Beekmantown (Lower Siluric) were laid down. Then followed the deposition of the highly fossiliferous Trenton (Lower Siluric) limestones including the Lowville and the Black River limestones. The fairly clear waters full of animal life then gave way to the muddy waters of the Utica, when the Utica shales (Lower Siluric) were deposited. At this time the Adirondack region was probably all under water. Next came an uplift on the east and northeast where depositions ceased. On the south and southwest, however, deposition continued and the successive formations of the Siluric and Devonic above the Utica shale were laid down. These Paleozoic formations may now be seen as one passes from the Adirondacks southward to the southern border of the State.

The last period of igneous activity in the Adirondacks occurred some time after the close of the Lower Siluric. This activity was of minor extent and showed itself in the form of dikes.

At some time after the deposition of the Utica shale the rocks, especially along the southern border, were deformed chiefly by faulting. A series of these faults extends across the Mohawk valley. The western Adirondacks, including the Port Leyden quadrangle, have been subjected to erosion for a vast length of time, certainly since the close of the Paleozoic and more than likely since the Devonic. During this great lapse of time a large amount of material has been removed. Doubtless the whole Port Leyden quadrangle was at one time covered by the Utica and Lorraine shales, which have all been removed except along the western side.

The superficial deposits, such as the sands and gravels which are so prominent in the Port Leyden district, were formed by, or along the border of, the great ice sheet of the Glacial age. From the geological standpoint this ice sheet was present only quite recently and covered most of New York State.

TOPOGRAPHY AND DRAINAGE

The Black river valley may be looked upon as the principal topographic feature along the western border of the Adirondacks, and the Port Leyden quadrangle represents a considerable portion of this valley where it is deepest. Black river enters the quadrangle at the southeast corner at an elevation of 1000 feet and, after following a northwest-north course, leaves it near the middle of the northern boundary at an elevation of about 740 feet. From the river eastward there is a general upward slope toward the Adirondacks. Facing the river there is a steep slope, which within 2½ miles, passing eastward, gives way to a generally level sand-flat area lying at an elevation of from 1200 to 1300. Along the eastern edge of the map several points reach altitudes of from 1300 to 1340 feet.

Passing westward from the river the general rise is much more rapid. Two terraces are here well developed from the latitude of Port Leyden northward. The lowermost terrace is from 2½ to 4 miles wide and has a steep front rising from 300 to 400 feet just west of the river. The upper terrace is known as Tug hill whose very steep eastern front rises from 400 to 450 feet and makes up the western portion of the quadrangle. The highest point on this side of the river is Gomery hill, near the western edge of the map, which shows an elevation of nearly 2100 feet, while altitudes of 1800 to 1900 feet are common. This high ground to the west of the river is a part of the broad high land area which lies between Black river and Lake Ontario. It is interesting to note that the elevations of the western portion of the quadrangle are much greater than those of the eastern or Adirondack portion. In order to reach elevations of 2100 feet or over it is necessary to pass 20 or 25 miles east of Black river into the Adirondacks to the high points around the Fulton chain of lakes.

Within the map limits Black river descends 200 feet, through a series of still waters and rapids, before reaching Lyons Falls. At Lyons Falls there is a sudden drop of 60 feet, but from this point northward to the map limit the river flows by a winding course through an old lake bottom [*see* p. 54] and the gradient is almost imperceptible. The largest tributaries to Black river from the east are Fall brook, Moose river, Fish creek, Otter creek and Independence river. By far the largest of these is Moose

river, one branch of which drains the Fulton chain of lakes. Chief among the tributaries from the west are Sugar river, Mill creek, House creek, Whetstone creek and Roaring brook. All the larger streams which have cut across the steep eastern front of Tug hill have there cut out deep narrow gorges locally called "gulfs." More special physiographic features will be described later.

PRECAMBRIC ROCKS

The Precambric rocks of the quadrangle represent a portion of the great Adirondack crystalline mass along its extreme western border. They occupy the eastern side of the quadrangle and make up a little less than one half its area. Except at the extreme south the Paleozoic-Precambric boundary line is everywhere to the west of Black river, but it keeps close to the river bottom. These crystalline rocks continue westward, under cover of the Paleozoics, for many miles. Considerable portions of the Precambric area are so deeply buried under glacial drift deposits that it is impossible to gain even the slightest clue as to the character of the rocks in those places.

Grenville gneiss

The Grenville formation takes its name from Grenville, Canada. It comprises a series of gneisses representing very ancient sedimentary rocks which have been so profoundly metamorphosed that the original sedimentary features have been largely obliterated. So far as can be definitely proved they are the oldest exposed rocks in the whole Adirondack region. That they are not actually the oldest rocks is evident from the fact that these sediments must have been deposited upon a still older floor. This very ancient rock floor, which may or may not represent a portion of the earth's primitive crust, has thus far not been proved to exist in the present exposures of the Adirondacks. It is barely possible that some of the gneisses still of doubtful age and origin may represent that ancient sea-floor.

Within the map limits the Grenville has been mapped in only three small areas, one at Kosterville, another at Lyonsdale, and a third to the east of Fowlersville. Grenville rocks are unquestionably present in much greater force than these small areas seem to indicate but they are always so thoroughly involved with other gneisses that they can not be represented on the geo-

logic map as such. Occurrences of this kind will be described later.

One of the strongest proofs of the sedimentary origin of the Grenville is the presence of limestone beds in the formation. Such limestones have been described by Smyth[1] in the Diana-Pitcairn area some 30 miles northward and also at the Fulton chain of lakes some 25 miles eastward. A little has been found by Mr D. H. Newland in the Little Falls district and also on Moose river a few miles east of the Port Leyden quadrangle. The latter occurrence is the closest to the Port Leyden quadrangle so far known. The writer has found no actual limestone on either the Remsen or the Port Leyden sheet although certain gneisses usually associated with the limestone are present. The statement may be repeated that, whereas Grenville limestone is common along the northwestern Adirondacks, it is only sparingly represented along the southwestern border.

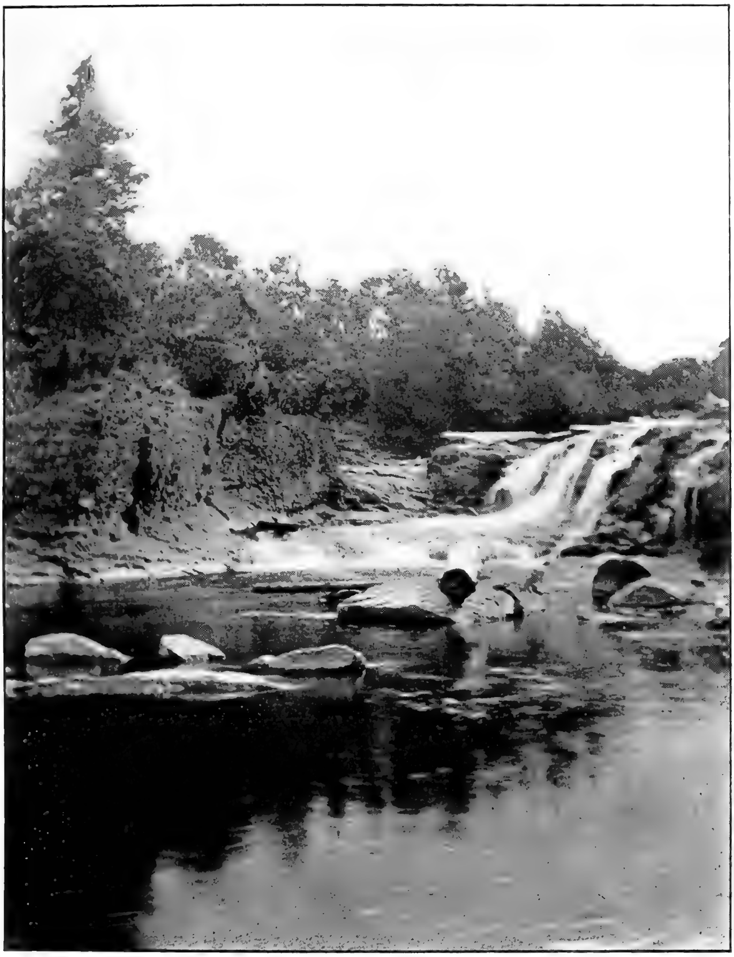
The fact that commonly the Grenville rocks here and elsewhere are in alternating layers which stand out in sharp contrast because of marked differences in composition and color leads to the belief that these bands are due to differences in original sedimentation. At times the gneiss is composed of almost pure quartz and could scarcely be of igneous origin.

Graphite is a form of crystallized carbon and of organic origin. Its presence as flakes in certain of the Grenville gneisses, including some within this quadrangle, affords a strong argument in favor of the sedimentary origin of those gneisses. Garnet is frequently present, often in great abundance, and it is rather more common in metamorphosed sediments.

Of the three areas above mentioned, each has certain distinctive features and hence they will be separately described. Thus in the Kosterville area the rocks are mostly quartz-sillimanite gneisses in thin layers and weathering to a rusty brown. They are not sharply separated from the neighboring rocks and some feldspar-garnet gneisses appear near the northern border of the area and along the river below Shuetown. The dip of the foliation is northward while the strike is about n. 60° e. which is the same as for the surrounding rocks. The specimens here described were taken from the fine exposures just below the bridge across Moose river. Microscopic study shows one

[1] Crystalline Rocks of the Western Adirondack Region. N. Y. State Mus. 51st An. Rep't. 1897. 2:469–97.

Plate 1



W. J. Miller, photo

Grenville gneiss just below the Moose river bridge at Goulds Mill. The rock is here practically a thin bedded quartzite.

specimen to be made up as follows: quartz 75%; sillimanite 12%; and with the long axes of the glistening needles parallel to the rock bands; enstatite 5%; magnetite 3%, and changing to leucoxene; pyrite 2%; garnet 2%, and often completely enveloping the magnetite; together with a little zircon and badly decomposed biotite. Another specimen shows from 85 to 90% of badly cracked quartz; 1 or 2% each of hornblende, pyrite and sillimanite with a little zircon; while the rest of the rock is made up of gray, uncrystallized, yellow-stained, decomposition products of hornblende and biotite. Certain other layers are slightly feldspathic. The most striking features in the composition are the very high quartz content, the almost complete absence of feldspar, and the dearth of dark colored minerals. The rock thus appears to have been an almost pure sandstone which has been metamorphosed to a quartzite. The rock is highly cataclastic and that the mass has been subjected to a great pressure is proved by the local folds and by the general crushed appearance of the exposures [*see* pl. 1]. In the field the rock has a decidedly sedimentary look and we have here a fine example of the Grenville which does not appear to have been very profoundly changed from the original sediment. Where these gneisses grade into the surrounding mixed gneisses some feldspar and a larger percentage of dark colored minerals are present.

The Grenville rocks in the Lyonsdale area are chiefly feldspar-garnet-mica gneisses. The gneissic structure is here greatly accentuated by the alternation of light and very dark gray layers which are usually from a few inches to a foot or more in thickness. A thin section of the light gneiss shows quartz 75%; feldspar 15 to 18%, mostly oligoclase to labradorite, but with a little microperthite; biotite 5%, and garnet 2 or 3%. In the dark gneisses the quartz is proportionately less prominent while the biotite may run as high as 35 or 40%. Both the light and dark rocks are often very garnetiferous. In some specimens a few small flakes of graphite were noted. The original sediments here were probably somewhat carbonaceous shales and shaly sandstones.

The rock bands show a northward dip at a high angle and a strike of n. 40° e. On the north side the exposures are not good but the Grenville does not seem to be sharply separated from the surrounding rocks, while on the south side, along Moose river, there is exhibited a very sharp contact between the Gren-

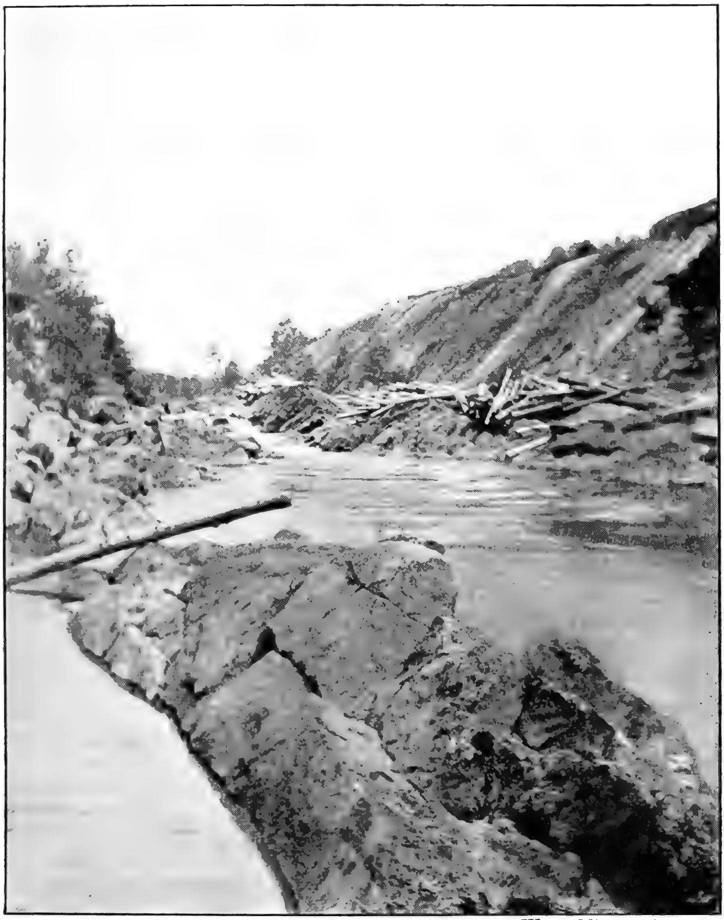
ville and the syenite. The more resistant syenite here forms a high, steep rock-wall on the south side of the river, while the less resistant Grenville gneisses have been deeply trenched by the river [*see* pl. 2]. Moose river really bears about n. 40° e. here and parallel to the foliation instead of nearly east and west as shown on the map.

In the area east of Fowlersville the Grenville rocks are chiefly pyroxene gneisses. The gneissic structure is highly developed and accentuated by the alternations of light and dark colored bands although none of the rocks are very dark colored. The bands are seldom more than a few inches thick. Microscopic investigation shows the common rock to be made up as follows: 40 to 50% of quartz; 25 to 30% of large, bright green, pyroxene crystals, sometimes slightly pleochroic; about 25% of feldspar, mostly orthoclase together with a little acid plagioclase; 3 to 5% each of hypersthene and enstatite; and a little bronzite and white pyroxene. Judging by the composition the sediments from which these rocks were derived were probably shales or shaly sandstones possibly somewhat calcareous. These gneisses are very similar to those referred to by Smyth as being directly associated with limestone. Although no limestone is here seen in outcrop, it is possible that some does occur along the east side of the area which may thus account for the distinct depression (now drift-filled) along that side and from which some softer or less resistant material has certainly been removed by erosion. Associated with these gneisses are a few layers rich in basic plagioclase feldspar and poor in pyroxenes and which have the appearance of igneous rocks. This Grenville area forms a long, narrow ridge which stands out as a distinct topographic feature. Moose river has cut a channel across this ridge. The rocks dip at an angle of 40° or 50° westward and strike almost due north and south. Outcrops of syenite have been found on all sides of, and pretty close to the Grenville mass. There are no sharp contacts visible but it seems certain that we are here dealing with a long, narrow inclusion of the Grenville in the syenite. This matter will be further discussed below under the heading "Syenite gneiss."

Syenite gneiss

As indicated on the geologic map, syenite gneiss makes up a considerable portion of the known Precambric area. From the standpoint of both composition and structure it is very uniform

Plate 2



W. J. Miller, photo

Moose river gorge just east of Lyonsdale. The rocks in the bed of the river are garnetiferous gneisses belonging to the Grenville. The high, steep rock on the right side is syenite which is in sharp contact with the Grenville.

over pretty large areas and it is clearly the most homogeneous rock mass among the Precambrics. The typical rock is a quartz-hornblende syenite always showing the granitoid texture. The quartz content varies a good deal but apparently without otherwise affecting the rock. The dark colored minerals are always very subordinate in amount. On weathered surfaces the color of the rock varies from a light brown to a reddish brown, while the color of the fresh rock varies from a sort of greenish gray to a light gray. The rock is nearly always medium grained although somewhat variable in this respect. In the field the rock always clearly exhibits a gneissic structure which usually can not be made out in the hand specimen. A distinct banding is seldom shown except at times near the borders where the syenite grades into the surrounding rocks. The minerals are roughly arranged with their long axes parallel to the strike of the foliation which ranges from n. 30° to 70° e. Such an arrangement of the dark colored minerals causes the foliation to be more evident, but they appear like wavy streaks which are seldom continuous for more than a few inches or a foot. The homogeneity of this syenite and its lack of distinct banding serve to separate it from the other Precambric rocks in the field.

The only noteworthy departure from homogeneity is to be found in the presence of occasional small dark basic patches in the syenite. These patches nearly always show abrupt terminations and to all appearances they are true inclusions. They are rich in hornblende and biotite and are invariably arranged with their long axes parallel to the gneissic bands of the syenite. Such inclusions may be seen in the field southeast of Denley; near where Miller brook enters the quadrangle; and probably best in the large exposures southwest of Partridgeville. Most of the syenite outcrops are, however, entirely free from such inclusions.

A number of syenite areas are shown on the accompanying geologic map. Of these the southernmost one extends from Denley southeastward to Hawkinsville and represents probably the purest and most typical syenite of the region. Fine exposures occur in the fields southeast of Denley and in the vicinity of Hawkinsville. A large area extends from Miller brook northward to Moose river with good outcrops along Fall and Miller brooks; at Fowlersville and for 2 miles southward; and just east of Lyonsdale. Another large area occupies the northeastern

portion of the quadrangle with fine exposures between Brantingham lake and Partridgeville and also where the road leaves the map east of Brantingham post office. The area between Greig and Donnattsburg shows many large outcrops of rock which here as well as around Partridgeville are more quartzose than usual. Smaller patches of rather quartzose syenite are shown at Lyons Falls and in the river bottom east of Glenfield.

The rock exposed in the quarry southeast of Denley may be taken as typical of the best syenite of the quadrangle and a detailed description of this type will now be given. In thin section fresh feldspar is seen to be the most common mineral which makes up 75 to 80% of the rock. Much of the feldspar is present as microperthite usually in large crystals and with the microperthitic structure beautifully exhibited. There is also a considerable percentage of another feldspar, presumably anorthoclase, which is characterized by a sort of moire or clouded appearance. There is a small amount of plagioclase feldspar ranging from oligoclase to andesin. The second most common mineral is quartz of which there is 12 or 15%. The quartz grains are very variable in shape and size and are frequently broken as a result of pressure. Of the dark colored minerals hornblende and biotite make up about 5% of the rock. The hornblende is the common green variety with usual pleochroism and shows frequent alterations to chlorite. 1 or 2% of magnetite, sometimes with leucoxene borders, is also present. Beside these a few small crystals of zircon, apatite, and zoisite may be seen nearly always as inclusions.

A study of the thin sections from the different syenite localities shows a range of minerals as follows: Feldspar 60 to 80% — microperthite always abundant, anorthoclase none to 20%, oligoclase none to 10%; quartz 15 to 30%; hornblende none to 5%; biotite none to 3%; magnetite none to 3%, and zircon, apatite and zoisite are nearly always present in very small amounts. In one or two cases a little garnet has been noted. The cataclastic structure is always more or less well developed in the syenite, sometimes being very prominent, which shows that the rock must have been subjected to a pretty severe dynamic metamorphism.

In Cushing's[1] typical syenite at Loon lake and Smyth's[2] typi-

[1] Geol. Soc. Am. Bul. 1899. 10:177–92.

[2] *loc. cit.* p. 473.

cal rock in the Diana-Pitcairn area, the dark minerals, especially pyroxene, are prominent constituents, while in the Port Leyden district the pyroxene is always absent and the dark minerals never amount to more than 7 or 8%. Otherwise the rocks are very similar. In passing northwestward from Little Falls to Port Leyden the syenite loses its pyroxene and the microperthite becomes more prominent than the anorthoclase.

It is now well established, especially by the excellent work of Smyth,[1] that the syenite is a plutonic igneous rock which has been intruded into and is therefore younger than the Grenville. The evidences from the Port Leyden region are clearly in harmony with this view. Thus the Grenville area east of Fowlersville is surrounded by pure syenite and the writer is convinced that we have here a good example of a large Grenville inclusion in the syenite. Significant in this connection is the fact that the strike of the foliation in the Grenville is north and south while that of the nearby syenite is about n. 30° e. This would be expected especially where large sedimentary masses were caught up in the molten syenite. Near Lyonsdale, on the south side of the river, the syenite and Grenville are in sharp contact while north of the river they appear to blend into each other. Around Kosterville no sharp contacts are seen but the syenite and Grenville seem to be mixed around the borders of the Grenville. Referring to similar phenomena farther northward Smyth[2] says: "Some of these inclusions are clearly defined with sharp boundaries but others are somewhat blended with the surrounding syenite as though they had undergone a partial melting." The small basic inclusions above mentioned and the very intimate mixture of syenite and Grenville on a large scale as described below also argue for the intrusive character of the syenite.

Granitic syenite gneiss

In the northern portion of the quadrangle, and on either side of Black river, two areas of granitic syenite gneiss are shown on the geologic map. These areas are probably continuous under the broad drift-filled valley bottom. This rock is almost certainly a granitic phase of the normal syenite above described, and, since the one rock grades into the other, the drawing of a boundary line must of necessity be an arbitrary matter. In

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[1] *loc. cit.*

[2] *loc. cit.* p. 477.

order to distinguish the granitic syenite from the normal syenite several features, given in the following description, must be considered.

The rock is not only clearly gneissoid but also distinctly banded. The rock bands are straight and rather persistent and the minerals are commonly arranged with their long axes parallel to the foliation. Frequently the "leaf gneiss" effect is beautifully shown because of the flattening out of the quartz and feldspar crystals. The color of the typical rock is red although at times gray bands are present. The size of the grain is rather variable but mostly pretty coarse. At times the quartz and feldspar crystals are almost porphyritic. The average quartz content is noticeably higher than in the normal syenite and commonly the more weathered surfaces show numerous projecting quartz crystals; often the rock might well be called granite. The granitic syenite also lacks the homogeneity of the ordinary syenite. In the larger exposures of the typical red quartzose gneisses there are occasional bands of gray, less quartzose gneisses very similar to the normal syenite.

Another noteworthy feature is the presence of long, narrow patches or inclusions much like those sparingly present in the ordinary syenite, but they are here much larger and more numerous. They are always drawn out perfectly parallel to the foliation planes but they are seldom more than 30 or 40 feet in length. They are composed of about equal parts of badly decomposed basic plagioclase and brown hornblende with which are associated thin layers of almost pure biotite. These biotite layers often give the rock a decidedly schistose appearance. The presence of these basic patches has doubtless aided in the production of the distinct banding of the granitic gneiss during the process of dynamic metamorphism. In this connection the writer has read the recent paper[1] by Professor Adams which deals with the origin of the amphibolites in the Glamorgan granite of Ontario, Canada. He says: "Here the limestone (Grenville), toward the granitic contact, passes gradually over into amphibolite, the latter being undoubtedly produced by the alteration of the former. . . The granite, furthermore, not only penetrates the (limestone) series, but floats off masses of the altered rock which in the form of bands, streaks, and isolated shreds are seen thickly scattered through the granite in the

[1] Jour. Geol. 1909. 17:8.

vicinity of the contact and which while less abundant, are found throughout practically the whole extent of the bathylith." Judging from his descriptions of the amphibolites, the inclusions in the Port Leyden region are very similar to them and, although we have here no such positive evidence for their origin, the explanation above given by Professor Adams becomes very suggestive at least.

In a general way at least, another distinction from the syenite is the more complete granulation of the granitic gneisses. Under the microscope the cataclastic structure is always well exhibited, sometimes to a remarkable degree. The quartzes were most badly broken by the grinding action and strain shadows are common.

In thin section the typical red granitic syenite from near the lower road crossing on Otter creek is seen to consist of about 60% of feldspar; 35% of quartz; 3% of hornblende; 2% of magnetite, and a very little zircon and apatite. The feldspar is chiefly microperthite accompanied by some anorthoclase and a little oligoclase. Red hematite stains are common in the sections. Closely associated with this typical rock, but always in subordinate amount, is a gray, less quartzose and more truly syenitic rock. In all of the sections of the granitic syenite examined the feldspar ranges from 60 to 70%. Microperthite is the chief feldspar, while anorthoclase ranges from absence to 20%, and oligoclase never exceeds 5%. The quartz range is from 25 to 40%. Hornblende is always present but never above 5%. Biotite is often absent and never exceeds 2%. From 1 to 4% of magnetite always occurs. Small crystals of apatite and zircon are common.

It seems certain that this red granitic gneiss is a differentiation phase of the normal syenite gneiss. Except for the greater granulation and somewhat higher quartz content, microscopic study shows no difference between the rocks. In the field no sharp line of separation can be drawn. The normal syenite in general seems to become more quartzose toward the north so that in this respect, at least, the syenite around Partridgeville closely approaches the granitic syenite. The writer is inclined to the belief that the passage from one rock to the other is much like that described by Smyth in the Diana area some 20 or 25 miles northward. He says:[1] "Passing southward from the latter (limestone formation) the syenite at first slowly and irreg-

[1] *loc. cit.* p. 481–82.

ularly then more rapidly increases in gneissoid structure till at a distance of from 3 to 5 miles from the limestone a region of red hornblende gneiss is reached. . . West of Natural Bridge in Jefferson county the syenite unquestionably passes over into a very perfect red gneiss. . . Both in the field and under the microscope the gradual change of the rock can be followed through every step." The same sort of a change has been observed by Cushing in the Tupper Lake syenite.[1]

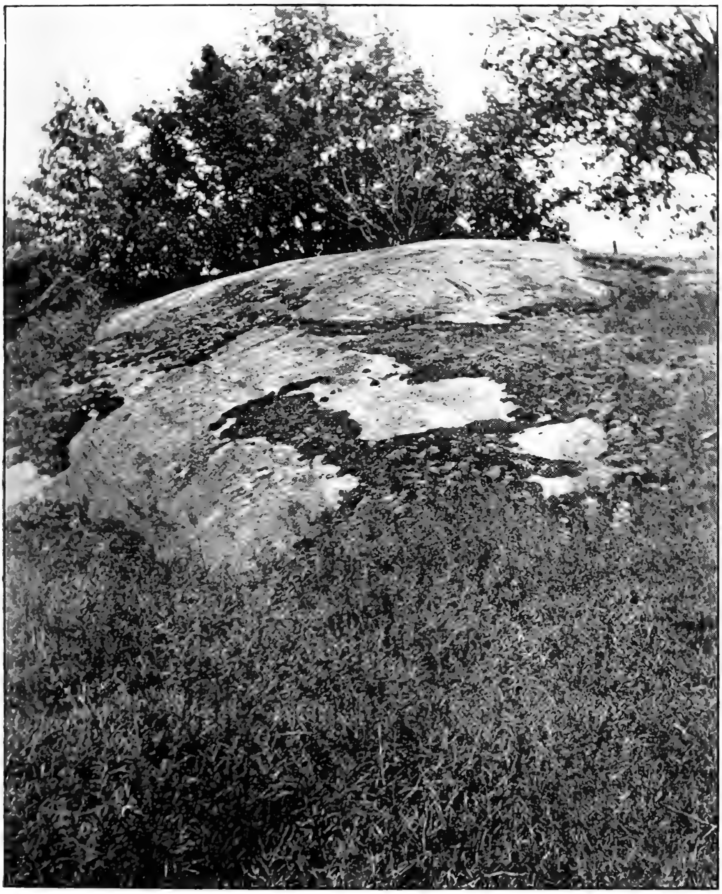
Syenite-Grenville mixed gneisses

A considerable portion of the known Precambric rock area has been represented upon the geologic map as being made up of various mixed gneisses. These gneisses include a great many rock varieties which make up a heterogeneous mass. After a careful study of these gneisses the writer is fully convinced that, for most part at least, they represent a more or less intricate mixture of the syenite and Grenville rocks. Some of these gneisses are admittedly of uncertain origin. Certain small patches within these areas are undoubtedly rather pure Grenville, while others seem to be pure syenite, but the small scale of the map does not permit these to be separately shown. Sometimes the syenitic and sometimes the Grenville facies predominate. These rocks are everywhere thoroughly gneissoid and they are generally well banded except in some of the more syenitic masses. The " leaf gneiss " structure is at times well developed.

It has already been stated that the syenite is intrusive into and younger than the Grenville and that the Grenville areas must be regarded as large inclusions. A study of the syenite-Grenville mixed gneisses furnishes convincing evidence of the same kind. Actual inclusions of undoubted Grenville may occasionally be seen within the syenitic masses. Such inclusions may be seen in the vicinity of Lyons Falls; ½ mile north and 1 mile east of Port Leyden; 1½ miles above the mouth of Miller brook; 1 mile above the mouth of Fall brook, etc. As already suggested, the writer is of the opinion that the Grenville was often either partially or wholly incorporated into the syenite by fusion when the latter came up in a molten condition. Various rock types formed in this way would depend partly upon the degree of metamorphism and partly upon the character of the Grenville. The masses of rather syenitic looking rocks which

[1] N. Y. State Mus. Bul. 95, p.323.

Plate 3



W. J. Miller, photo

A typical Precambric exposure ½ mile north of Lyons Falls station showing the smoothed, glaciated character of the surface. The rock is a syenitic facies of the syenite-Grenville mixed gneisses.

are quartzose and garnetiferous may be accounted for by some such process.

Three syenite-Grenville areas are shown on the map. The largest of these extends from Denley station to north of Greig, a distance of nearly 12 miles, while the width averages something like 3 miles. In the southern portion of this area the Grenville is present in greater force than the syenitic or granitic rocks, while in the northern the reverse is true except possibly in the vicinity of Greig. Within this area there seems to be good evidence for the former existence of very ancient Grenville rock belts or structure lines which extended in a northeast-southwest direction. Thus pyroxene gneisses are found in the area east of Fowlersville; in small outcrops 1½ miles east of Port Leyden; and 1½ miles north of Denley, and these are all arranged along a northeast-southwest line. A belt of feldspar-garnet gneisses shows a similar strike and extends from Lyonsdale to Port Leyden. Quartz-sillimanite rocks much like those at Kosterville have been noted in small exposures from ½ to ¾ of a mile north of Port Leyden and this suggests another northeast-southwest belt. A less well defined belt is garnetiferous and passes through Lyons Falls. Still another belt, in which garnet-sillimanite gneisses are commonly found, passes northeast and southwest through Greig. It seems pretty certain that before the intrusion of the syenite, these Grenville belts were continuous and well defined and that as a result of the intrusion they were all cut up leaving only here and there masses of the pure Grenville.

Of the two smaller syenite-Grenville areas, one lies about 2 miles north of Fowlersville and the other around East Martinsburg. These rocks are quartzose syenites often containing garnets and more or less intermingled with Grenville.

The great variety of rock types making up this complex and their gradations from one type to another make it difficult to give a proper idea of them by description. Microscopic study of numerous thin sections shows the presence of all the minerals of both the Grenville and the syenite and in addition to them microcline which often occurs as a prominent feldspar. The following brief descriptions include most of the leading types:

1 Syenitic facies. These are often practically indistinguishable from the normal syenite. They are usually, however, pretty fine grained and under the microscope nearly always show a highly cataclastic structure. They frequently contain microcline

feldspar and a large proportion of quartz and the dark colored minerals. Thus a specimen from along the railroad 2½ miles north of Lyons Falls contains 75% of microperthite; 20% of quartz; 5% of magnetite, biotite and hornblende, together with a little zircon. Another from ⅔ of a mile southwest of Goulds Mill contains 65%, in about equal amounts, of microcline, microperthite and plagioclase (oligoclase to labradorite); 25% of quartz; and 10% of biotite and magnetite. North of Lyons Falls, along the railroad, similar rocks often carry 30 to 40% of quartz with sometimes a little anorthoclase and they greatly resemble the granitic syenite.

2 Grenville facies. Small exposures often show very pure Grenville as for example at the river dam ½ mile north of Port Leyden. A thin section from here shows 80% quartz; 10% sillimanite; 8% magnetite and 2% biotite, together with a little zircon. Again, a typical pyroxene, quartz gneiss is associated with syenitic rocks 1½ miles above the mouth of Miller brook. A Grenville facies carrying garnets occurs in the vicinity of the paper mill at Lyons Falls.

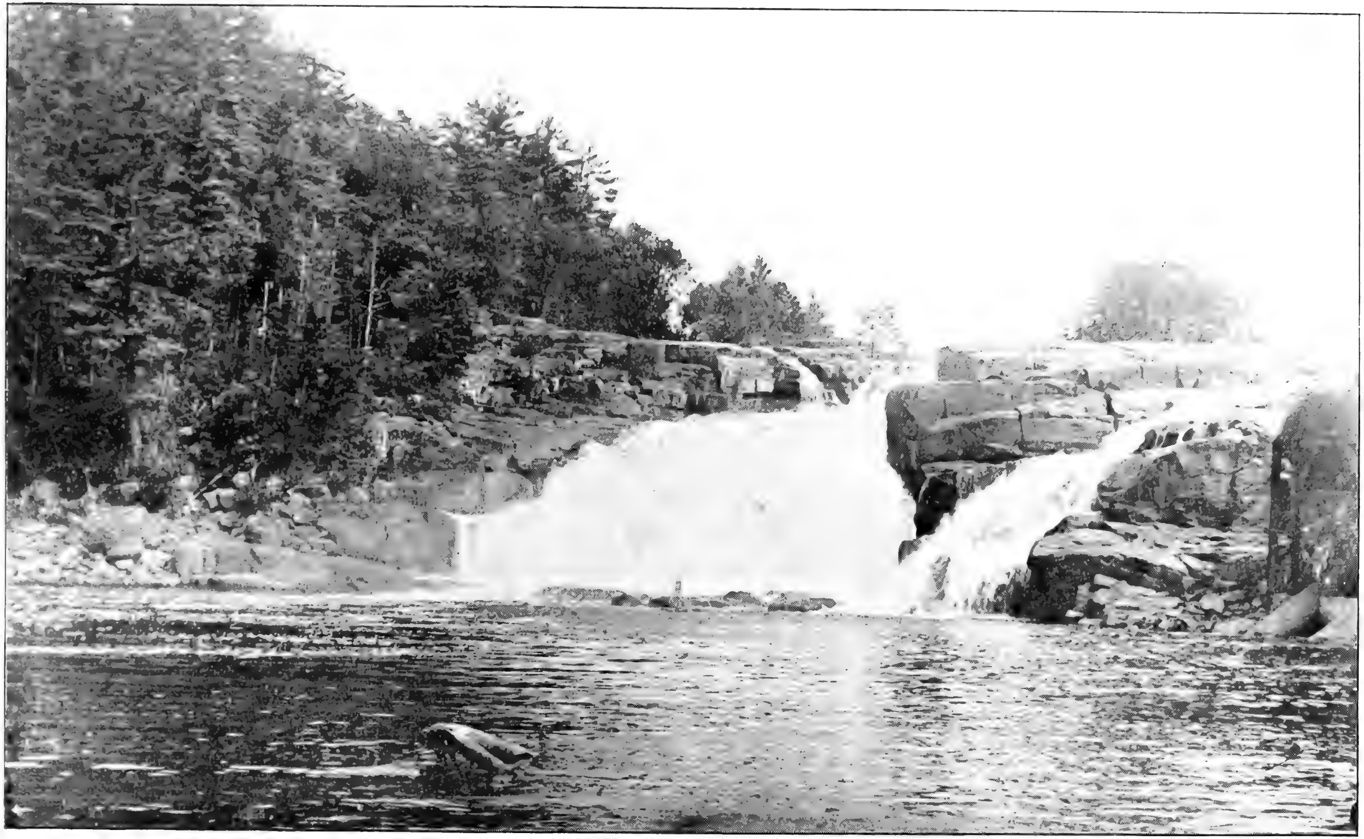
3 Garnetiferous gneisses with a general igneous appearance are very common. Such a rock 2 miles east of Port Leyden shows 65% of microcline and microperthite; 20% of quartz; 5% of hornblende and biotite and 10% of augite, magnetite, garnet and zircon. A similar type much richer in garnet and almost free from dark minerals occurs in the river bed at Port Leyden. Another type from 2½ miles east-southeast of Greig shows 65% of plagioclase (oligoclase to labradorite); 30% of quartz and 5% of biotite, garnet, magnetite and zircon. The origin of these gneisses is doubtful but they may have been formed by a thorough mixing of Grenville masses with the molten syenite. The garnets in these rocks are frequently an inch or more across.

4 A very gneissoid, rather dark rock, which is fairly common, is rich in plagioclase, quartz and biotite. An example from ½ mile south of Lyons Falls contains 45% of plagioclase (oligoclase to andesin); 40% of quartz; 10% of biotite; 2% of hornblende and 3% of magnetite, zircon and pyrite.

5 A very gneissoid, dark rock from 1½ miles east of Port Leyden contains 50% of microcline and plagioclase (oligoclase to labradorite); 20% of quartz and 10% each of green augite, biotite, magnetite and a very little garnet.

6 A type of dark, quartzless, gabbroic rock such as that at Lyons Falls dam contains 55% of plagioclase (oligoclase to labrador-

Plate 4



Falls of Black river at Lyons Falls. The rock here is a dark, gabbroic mass which has been mapped with the syenite-Grenville mixed gneisses.

ite); 40% of green hornblende and green augite and 5% of hypersthene, magnetite, biotite, zircon and apatite. This type is in contact with another gabbroic rock which has a considerable percentage of quartz and hypersthene and some microperthite.

7 Very dark, long, narrow patches which are probably inclusions are common. They usually consist mostly of decomposed hornblende and basic plagioclase together with some quartz, magnetite and biotite.

Undetermined Precambric areas

Unfortunately several large Precambric areas are so deeply buried under Pleistocene deposits that the character of the underlying rocks is entirely unknown. These areas have been so indicated upon the geologic map.

PALEOZOIC ROCKS

The Paleozoic rocks occupy a little over one half the area of the quadrangle on the west side. Except at the extreme south they always lie to the west of Black river. The maximum thickness of the Paleozoic formations is approximately 1500 feet.

Potsdam sandstone

The Potsdam sandstone is of upper Cambric age and is the most ancient sedimentary formation bordering the Adirondacks. It is not present in outcrop in the Port Leyden quadrangle nor in fact along the whole southwestern border of the Adirondacks, although it is most likely present beneath the later formations. South of Port Leyden the deep wells at Utica and at Rome show a basal sandstone which is more than likely the Potsdam. West of Port Leyden the Potsdam, according to Orton,[1] is most certainly present in the deep wells of Oswego county at Central Square, Parish, Pulaski and Stillwater. The nearest outcrops of the sandstone are something like 20 miles north-northwest of the Port Leyden quadrangle and from there northward to the St Lawrence it is a common surface rock.

Pamelia limestone

The Pamelia limestone was named by Professor Cushing from a town in Jefferson county where he recently recognized it as a distinct formation.[2] Between the Potsdam and the Pamelia,

[1] Petroleum and Natural Gas in New York. N. Y. State Mus. Bul. 30. 1899.

Geol. Soc. Am. Bul. 1908. 19:155-76.

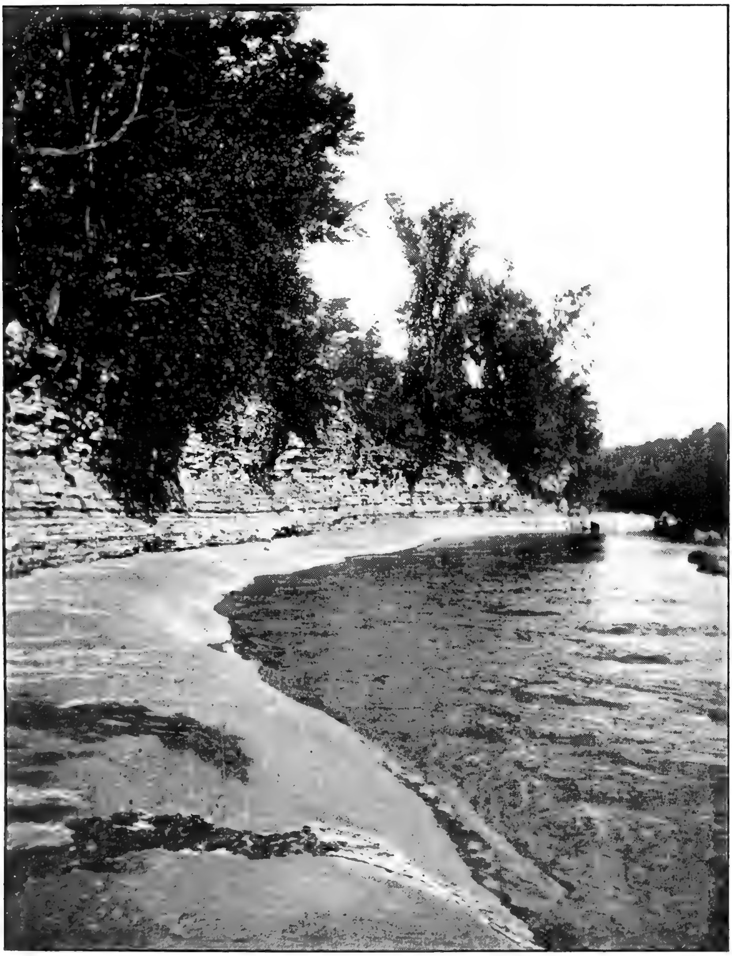
in the St Lawrence and Champlain valleys, other formations come in whose exact relationships have not yet been made out. According to Ulrich the Pamelia is to be correlated with a part of the Chazy of the Champlain valley. For a long time the Pamelia had been described and mapped as Beekmantown limestone, but it now seems to be pretty well established that the true Beekmantown is not present along the northwestern Adirondacks.

The Pamelia formation (Lower Siluric) is the oldest sedimentary mass exposed within the limits of the quadrangle. Its outcropping edge, which extends from north to south across the district, everywhere rests directly upon the Precambric rocks. Since it outcrops at the base of the steep slope facing Black river its surface exposure is small. The actual contact with the Precambric may be seen in at least three places as follows: Where the railroad crosses Roaring brook near Martinsburg station; along the creek 1⅓ miles northwest-north of Lyons Falls; and along the railroad ¾ of a mile north of Port Leyden. At a number of other places the contact is almost visible. The bed in actual contact with the Precambric is always a sandy conglomerate above which occur several feet of calcareous sandstones, then a few feet of bluish black, fossiliferous limestone, and finally thin to thick bedded, whitish gray to bluish gray, rather impure limestones which latter make up more than half the section. Many of the upper, gray beds are really magnesian limestones which may be burned for waterlime as has been done at Lowville. The conglomerate and sandstone at the base of the Pamelia represent the materials derived from the Precambric land surface as the sea encroached upon it. According to the observations of Professor Cushing on the Theresa quadrangle (northward), which are corroborated by the writer on the Port Leyden quadrangle, the basal conglomerate and sandstone represents a shifting upward horizon, due to overlap, as the sea encroached upon the land from west to east. These basal beds are more than likely to be correlated with the Rideau sandstone as described by Ami in Ontario, Canada.

Following is a detailed section made by Professor Cushing along Roaring brook (near Martinsburg station) and kindly furnished to the writer:

	Feet	Inches
4 inches of blue gray calcareous shale above and 9 inches of same beneath with a 4-inch layer of mottled blue limestone like that beneath	1	5

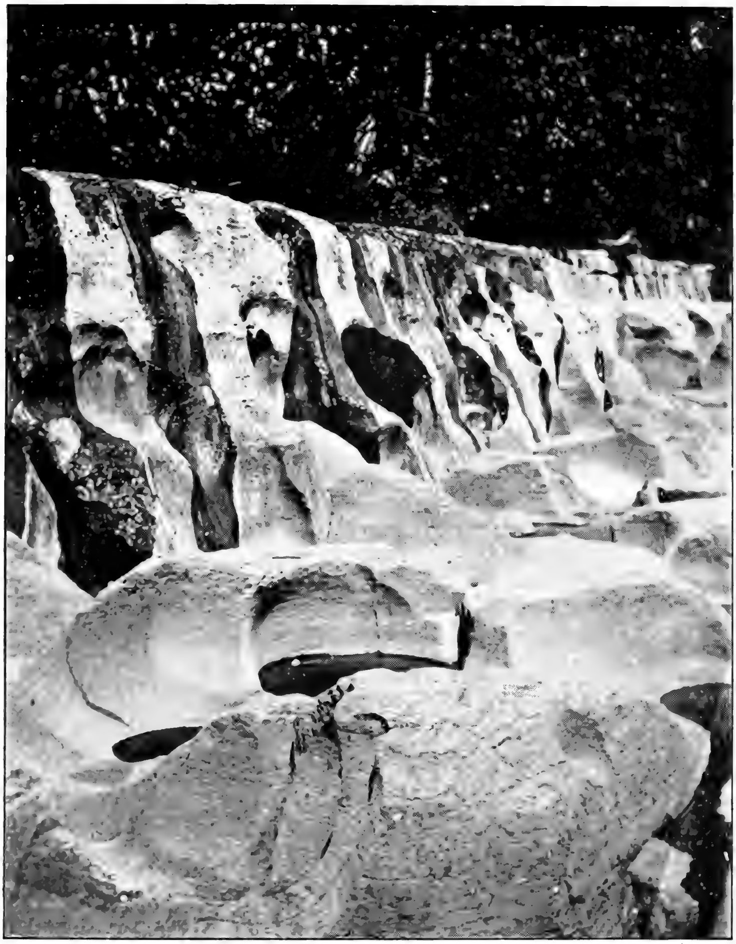
Plate 5



W. J. Miller, photo

View along Black river, 1¼ miles above the mouth of Sugar river, taken to show the sharp contact between the Trenton and the Black River limestones. During high water the thin bedded Trenton limestones have been worn back to leave exposed a distinct platform of the underlying massive Black River limestone.

Plate 6



W. J. Miller, photo

A group of "potholes" in the bed of Sugar river ½ mile below the railroad crossing. The rock is Black River limestone.

	Feet	Inches
A massive bed of blue granular limestone, mottled and laminated and with pebbles of blue dove limestone	1	6
Hard, gray white limestone with spots of crystallized calcite	....	9
Bluish gray, thin bedded limestone, with ripple marks and ostracods	2	2
Shaly, dirty white mud limestone beds, mud cracked	1	6
Bluish subgranular, thin bedded limestone	....	9
Blue dove, hard, mottled limestone, shaly below, traces of fossils	1	4
Hard, gray granular limestone, pinkish tinge, much calcite	....	6
Thin, ripple marked, dirty white, mud limestone beds	1	......
Hard, blue gray subgranular limestone, sand grains and ostracods above	2	6
Hard, gray white limestone, less earthy than usual; calcite spots	....	9
Subgranular, blue, laminated limestone; welded contact with above	2	5
Very massive, gray white, earthy limestone, irregular splitting.	5	9
Massive blue dove limestone in two layers; laminated; styliolites and traces of fossils	1	9
Thin and thick bedded, blue subgranular limestone; massive basal layer; laminated; much mud cracked	7	9
Earthy, impure, gray white beds; massive and irregular splitting; lower 12–18 inches hard, gray white, calcite spotted, bunchy surfaced	3	11
Gray white, impure, earthy, blocky beds	1	8
Impure, gray white, reddish tinged, earthy limestone, with purer layer of reddish limestone at base; quite massive; summit less red	7	8
Bluish black, fine, hard limestone, like 2d beneath but unfossil.	1	......
Gray to blue gray, magnesian looking limestone in 3–6-inch beds	2	9
3 heavy layers of hard, bluish black limestone; ringing; multitude of small fossils, lamellibranchs, cephalopods, one-celled Tetradium, etc	4	7
Red and green, impure, calcareous, sandy mudstone, large sand grains; upper 6 inches thin bedded, rest massive	7	......
Very sandy firm green limestone, full of quartz grains	1	3
Hard, gray white, somewhat sandy limestone or dolomite; calcite spots	1	2
Hard, ringing, green, calcareous sandstone	....	10
Red, sandy, rotten shale	1	6
More solid, red and green calcareous sandstone; rots easily	4	......
Red and green, rotten, calcareous sandstone	....	9
Green and red arkose; perhaps calcareous	....	11
Conglomerate resting on Precambric	....	10
Total	71	8

Eight miles south of the above section and 1¼ miles northwest-north of Lyons Falls station another excellent section is shown along Mill creek where all the beds from the Precambric to the Trenton are exposed. Mill creek is not properly placed on the map here. Its true course is close to the town line between Turin and West Turin. By means of the hand level the writer has determined the thickness of the Pamelia here to be about 56 feet. The basal conglomerate, 1 foot thick, is followed by 10 feet of gray, calcareous sandstones and very sandy limestones with some sandy shale partings. Next come 4½ feet of bluish black limestones. Above this the beds are much like those along Roaring brook and their summit is here also capped by a limestone conglomerate.

Some 7 miles south of the Mill creek section and in the vicinity of Denley there are good exposures of the Pamelia. No complete section is visible but a study of all the outcrops makes it certain that the formation is here not over 20 feet thick. The basal conglomerate and sandstone underlies grayish, sandy, thick bedded limestones, while the whole is capped by the usual limestone conglomerate. The most southerly outcrops of Pamelia occur along Mile creek from ½ to 1 mile above its mouth, where the formation is apparently not over 10 or 12 feet thick. It disappears before the Remsen quadrangle is reached.

The thinning out to disappearance of the Pamelia in passing southeasterly may be entirely explained as due to overlap, since the formation came in from the west, as above shown, and rapidly thins out eastward. Its place of disappearance, most likely in the northeastern corner of the Boonville quadrangle, is some 9 or 10 miles east of a north-south line passing through the Roaring brook section where the Pamelia is over 71 feet thick. This represents an eastward thinning of 7 or 8 feet per mile which compares favorably with the rate of thinning noted by Cushing over the Theresa quadrangle. Of course, some of the thinning may quite possibly be due to a lack of deposition of so much material in the southern portion of the basin. It seems certain that the Pamelia is present in considerable force, under cover of later rocks, in the western part of the Port Leyden quadrangle and to some extent, at least, in the northern part of the Boonville quadrangle. In a letter Cushing says that what has heretofore been referred to as Beekmantown-Lowville passage beds in the region around Little Falls may in reality be a touch of the Pamelia there.

Plate 7

Falls of Sugar river just above the railroad bridge. The rock is rather heavy bedded crystalline Trenton limestone.

Lowville limestone

The Lowville limestone formation takes its name from the type locality at Lowville a few miles beyond the map limits to the northward. It was formerly called the Birdseye limestone because of the spotted character of the surfaces due to the emergence of the calcite-filled tubes so characteristic of the formation. These calcite-filled tubes stand perpendicular to the stratification planes and were first thought to have been caused by a seaweed of the Fucoid type, but they are now referred to the genus Tetradium of the branching corals. Not all of the Lowville beds contain the Tetradium.

In the old State report by Vanuxem everything below the Trenton, in this region, was described under the heading "Black River limestone," but the following quotation shows that, on lithologic grounds, he recognized three divisions of the formation: "The cliff shows several distinct kinds of limestone, not being a homogeneous mass. The upper part is mixed irregularly with black shale. . . . The second division is of a lighter color, with less shale or impurities, more brittle, and contains the Fucoides demissus (Tetradium), etc. . . The third division, and which therefore forms the base of the cliff . . . is light colored, and the surface of some of the layers present mud cracks, showing the presence of shale. It is in these layers that the stone exists which is burnt for waterlime at Lowville."[1] His upper division corresponds to our Black River limestone, the middle one nearly to our Lowville, and the lower one nearly to our Pamelia.

Within the map limits the Lowville, together with the Pamelia, is present, except at the extreme south, as an almost continuous surface exposure or ledge facing the railroad. In spite of its considerable thickness its areal extent is small because of its outcrop along this steep slope. The Lowville beds are mostly bluish dove-colored, pure limestones in beds varying from a few inches to 2 feet thick. Some of the beds are mud cracked, others are shaly, while still others are fossiliferous commonly with the Tetradium. A notable feature is the presence of limestone conglomerate at several horizons. In passing downward this conglomerate is prominent where the pure dove limestones give way to the more impure bluish gray to whitish gray limestones and it is here where the line between the Lowville and Pamelia has been drawn. Within the quadrangle this line is a difficult one to draw with any great degree of accuracy.

[1] Geol. N. Y. 3d Dist. 1842. p. 42.

According to the work of Cushing and Ulrich farther northward, there is an unconformity separating the two formations, the time gap being represented by the upper portion of the Chazy of the Champlain valley. In the Port Leyden district, the change from the conglomeratic bluish dove limestones to the more impure whitish, sandy beds seems significant and may be due to an unconformity at this horizon. Certainly, however, the writer has found no evidence of any well defined or large unconformity between the Lowville and Pamelia.

In the Roaring brook section as measured by Cushing the Lowville is made up as follows:

	Feet	Inches
6-foot layer of Black River limestone; upper 3 feet full of chert	....	......
Mostly thin bedded blue dove limestone in 6-inch to 1-foot layers, full of Tetradium and other fossils, to base of Black River	7	8
Massive beds of blue dove limestone in 18-inch to 2-foot layers; only sparingly fossiliferous, but more or less Tetradium everywhere	17	4
Shaly, blue dove limestone	1	8
Blue, granular limestone full of fossils and much crystallized calcite	1	2
Ordinary blue dove limestone; lower portion full of gastropods; upper portion a limestone conglomerate with bunchy surface and Stromatocerium look; filling in above are 2–10 inches of shaly limestone	2	10
Thin bedded blue dove limestone	1	1
Massive blue dove limestone; few fossils and little calcite	2	......
Blue black dove limestone; full of fossils and crystallized calcite; thin bedded; shaly above	1	5
Gray, oolitic beds	2	2
Shaly, impure limestone beds blue dove color	1	4
Gray blue, subgranular limestone; calcite specks and spots	1	4
Massive, blue dove limestone; very fossiliferous; Tetradium abundant	2	10
Thin bedded to shaly blue dove limestone; mud cracked; many fossil fragments	3	6
Two massive blue dove beds with shale parting; conglomeratic; many fossils and calcite spots; not sure about Tetradium	2	8
Blue black dove limestone, notably conglomeratic; lots of fossil fragments and many calcite spots; irregular surface	....	9
Thin bedded, mud cracked, dove limestone	1	4
Blue dove limestone spotted with calcite; conglomeratic; many fossils; no Tetradium seen; abundant quartz sand grains on lower surface; probable base of Lowville	3	6
Total	54	7

A section measured by the writer 1½ miles north-northwest of Lyons Falls, and along Mill creek, shows about 54 feet of Lowville. This section is continuous with that of the Pamelia already referred to. Near Denley the section contains about 57 feet of the Lowville.

A comparison of the sections at these widely separated localities brings out some interesting facts, the chief one probably being that the formation shows almost exactly the same thickness throughout the whole distance. This is especially significant in view of the rapid thinning of the underlying Pamelia. Another fact is the great similarity of the beds in the different sections. Thus the basal conglomerate always lies from 54 to 57 feet below the summit, while another conglomerate apparently always lies about 26 or 28 feet below the summit and is associated with a heavy bed of pure dove limestone full of gastropods.

Near the west edge of the Remsen quadrangle, along Black river, there is no complete section, but the Lowville is probably not over 40 feet thick. On the Little Falls sheet the Lowville varies in thickness from 5 to 21 feet, while at Canajoharie it is absent altogether. Thus the outcropping Lowville along the southwestern Adirondacks shows a steady increase in thickness in passing from Canajoharie to Port Leyden.

Black River limestone

The Black River limestone is so named because of its typical occurrence along Black river. It is a hard, fine grained, dark colored to almost black, limestone which breaks with a smooth fracture. Interspersed through the limestone, in a very irregular manner, are small patches of black shale which causes the rock, on weathering, to break into lumpy masses. The appearance of the rock is pretty well shown in plate 6. After long exposure to the weather the surface color changes to a light gray. The rock is generally massive although two or three layers can usually be fairly well made out. Another distinctive feature of the rock, particularly the upper portion, is the presence in it of many irregular shaped black chert nodules. Among the abundant fossils are fine large specimens of orthoceratites and columnar corals especially well exhibited on the upper waterworn surfaces. Hall[1] says of the formation " from being characterized by a large number of peculiar fossils, though mainly belonging to a single family, it is regarded as worthy of separate notice. The principal and most prominent

[1] Palaeontology of N. Y. 1847. 1:46.

organic bodies in this rock are Orthocerata, some of which attain the length of more than 10 feet, and have a diameter of 1 foot or more. Associated with these are several species of Cephalopoda belonging to other genera, and some species of Gastropoda which subsequently appear in the succeeding limestone." These distinctive features cause the formation to stand out as a clearly defined horizon and there are many excellent exposures within the quadrangle.

Within the map limits the Black River limestone varies in thickness from 6 or 8 to 15 or 16 feet and although it is so thin it is persistently present. It is nowhere seen in outcrop on the Remsen quadrangle although it does most likely occur. In the vicinity of Little Falls it is occasionally present but only a few feet thick, while at Canajoharie it is absent altogether.

In connection with the Black River limestone certain erosion features are noteworthy. Directly overlying the hard, massive Black River beds are thin beds of Trenton with pronounced shale partings. The latter beds are more readily worn back than the former, the result being that the Black River nearly always stands out as a terrace or platform back of which the Trenton rises rather abruptly. This platform is of sufficient topographic importance to be shown on the contour map. At times of high water the Trenton is now being stripped off the Black River along Dry Sugar river and along Black river a little over a mile above the mouth of Sugar river. At the latter place the high water has cut back the Trenton limestone so as to leave a distinct and remarkably regular platform of Black River limestone which extends for several hundred yards. During low water the river occupies a channel which has been worn into the Black River limestone [*see* pl. 5].

The composition, texture, and massive character of the rock are favorable for the development of "potholes." A magnificent display of "potholes" may be seen along Sugar river (Dry Sugar river) from the canal crossing to near its mouth. The bed of the stream, which is here dry except during high water, is literally honeycombed with hundreds of "potholes," some of them attaining a depth of 6 or 8 feet and a diameter of several feet [*see* pl. 6].

Trenton limestone

The Trenton limestone has its type locality at Trenton Falls some 20 miles southward. From the standpoint of areal extent and thickness this formation is the second most important one

within the quadrangle. In a general way the Trenton here shows most of the features of the type locality. At Trenton Falls the formation is about 300 feet thick and the rocks are mostly thin bedded, impure, dark limestones with pronounced shale partings, except the upper 30 feet which are thicker bedded, gray, crystalline limestones. The following section shows that a marked lithologic change has taken place in passing from Trenton Falls to Port Leyden.

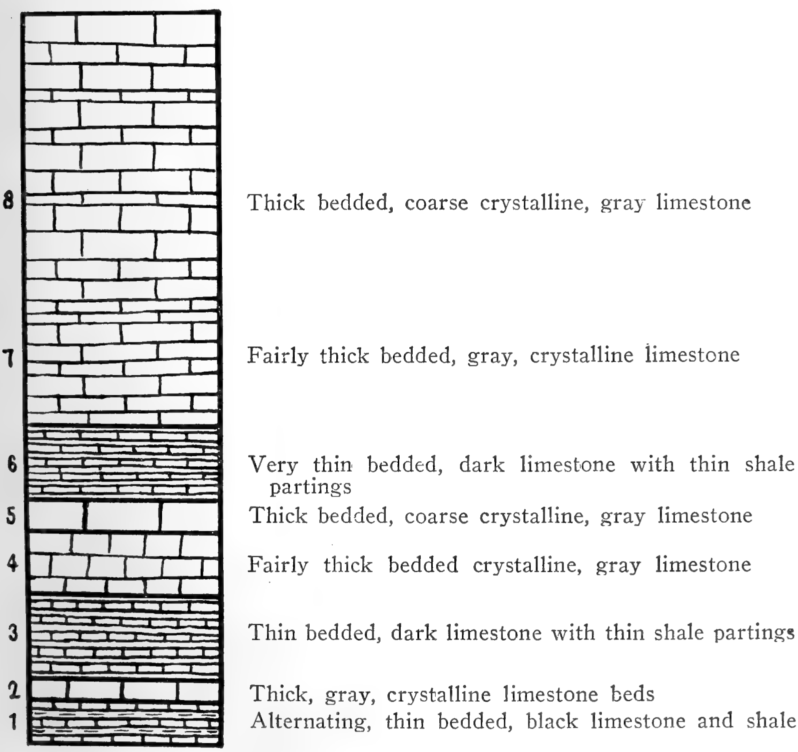


FIG. 1 Columnar section from base to summit of the Trenton limestone formation along Sugar river and Moose creek. The section is 350 feet thick.

More than half of the section is here made up of the gray, crystalline, heavy beds as opposed to only about 30 feet of such beds at Trenton Falls. Within the Little Falls quadrangle the heavy, crystalline beds are absent altogether, the upper Trenton being represented by the Dolgeville shales which are in reality alternating thin beds of impure limestone and shales. These and

other facts may be studied to best advantage by comparing the type section here with those of the Little Falls and Trenton Falls districts. The two last named sections may be found on page 38 of the Remsen quadrangle bulletin.[1] It is evident, therefore, that the upper Trenton sea in the Port Leyden district was much clearer water than the same sea in the Little Falls region. Also the change from the upper Trenton to the Utica was much more gradual at Little Falls as shown by the deposition there of the Dolgeville shales as a transition series. In passing northward from Sugar river to Martinsburg the pure, heavy bedded, crystalline limestones assume even greater importance.

The lowermost 20 feet of the Trenton are highly fossiliferous, thin bedded, alternating shales and limestones. These beds are in sharp contact with the underlying massive Black River limestone as may be seen along Sugar river; along Black river 1 mile above the mouth of Sugar river; along Mill, Douglass, and House creeks and Roaring brook.

Except for the shale area at Locust Grove, the Trenton limestone extends from south to north across the map as an unbroken belt whose width is from 2 to 3 miles. It forms the summit of the lower great terrace so plainly shown on the topographic map. Minor terraces are developed along the lines of outcrop of certain harder and more resistant strata within the formation. The villages of Talcottville, Collinsville, Turin, Houseville and Martinsburg all rest upon the Trenton. The larger streams have cut picturesque gorges through this limestone as for example on Sugar river, Mill creek, House creek and Roaring brook. The last named gorge is locally called "Whitaker's gulf."

Throughout all of Trenton time the ocean was fairly teeming with animal forms, especially brachiopods, trilobites, cephalopods, corals and crinoids. Many of the limestone beds are practically made up of fossil shells. The writer has made no detailed study of the fossils, but the forms are mostly the same as those decribed by Prosser and Cumings from the type locality at Trenton Falls. Hall has described and figured many of the forms from this limestone along the Black river valley. In the lowest Trenton beds the writer has seen specimens of orthoceras several feet long and 5 or 6 inches in diameter.

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[1] N. Y. State Mus. Bul. 126. p. 38.

Plate 8

Whitaker falls on Roaring brook 1 mile southwest of East Martinsburg station. The rock is Trenton limestone.

The thickness of the Trenton has been approximately determined in a number of places as follows:

	Feet
Along Moose creek and Sugar river	350
Between Port Leyden and Locust Grove	370
Along Mill creek	400
Along House creek	450
Along Roaring brook and Atwater creek	475

Thus, in a distance of 20 miles across the map, from south to north, the Trenton shows an increase in thickness of something like 125 feet or at the rate of about 6 feet per mile. Passing southeastwardly along the line of outcrop, the Trenton shows a progressive thinning. Thus at Remsen it is about 300 feet; near Middleville 200 feet; at Ingham Mills 100 feet; and at Canajoharie only 17 feet. Westward in Oswego county deep wells at Stillwater and Central Square show respective thicknesses of 670 and 747 feet.

Utica shale

The Utica shale formation shows practically the same characteristic features here as it does at its type locality at Utica. It is a very fine grained, dark gray to black, thin bedded shale. The black color is due to the presence of carbonaceous matter which may be readily burnt out, although, contrary to a current popular idea, nothing like a workable coal seam occurs within the formation Occasionally some of the layers are rather sandy especially toward the top. Toward the base of the formation some of the layers are several inches thick and are frequently calcareous and except for this the contact between the Utica and the Trenton is a sharp one. Because of the softness of the rock and the character of the outcrop, favorable to the development of talus slopes, the actual contact between the shale and limestone was nowhere observed. Many times, however, Trenton beds have been noted in such close proximity to the shale that the boundary line can be pretty accurately drawn. Such observations may be made along Atwater creek or Moose creek.

In spite of a considerable thickness its areal extent is rather small because it outcrops along the base of the steep slope forming the eastern fronts of Tug and Mohawk hills. Excellent sections are to be found along all of the larger streams which cut across this steep slope. Its broadest surface exposure is from Constable-

ville southward where the shale is thickest and the slope is not so great. An interesting erosion remnant, or outlier, separated from the main mass covers several square miles in the vicinity of Locust Grove.

The Utica shale is here not highly fossiliferous although certain fossils so common to the formation may be found in nearly every exposure. Among these are the Endoceras proteiforme of the chambered cephalopods, Triarthrus becki of the trilobites, and some graptolites. Animal life in the Trenton ocean was very prolific, but with the advent of the muddy Utica sea there was a great diminution in both the number of species and individuals.

Along the line of outcrop the shale shows a notable and steady decrease in thickness toward the north. Following are approximate determinations of the thickness within the quadrangle from south to north.

	Feet
Along Moose creek	300
At Constableville	260
At Turin	230
At Houseville	200
Along Atwater creek	180

Southeasterly along the line of outcrop the Utica increases in thickness. Near Remsen it is over 300 feet and near Little Falls about 600 feet. Westward in Oswego county it shows a thickness of 180 feet at Central Square; 120 feet at Fulton and 113 feet at Stillwater in the deep wells. Thus it is evident, in a general way along the southwestern Adirondacks, that the Utica is thinnest where the Trenton is thickest and vice versa, the two formations having nearly the same thickness on the Remsen quadrangle.

Lorraine shales and sandstones

The Lorraine formation received its name from the town of Lorraine in Jefferson county, some 30 miles northwest of Port Leyden. The rocks included under this heading are the same as those of the old "Hudson River group" of Vanuxem's report.[1] In the future the Lorraine beds will doubtless be subdivided, but more detailed work over a wider territory must be done before such subdivision is attempted. In the meantime, all the strata lying between the

[1] Geol. N. Y. 3d Dist. 1842. p. 60.

Plate 9

A view in Whetstone gulf. A short distance above this the gulf is much narrower. The depth is nearly 300 feet and the exposed rocks are the alternating shales and sandstones of the Lorraine.

Utica shale and the Oswego sandstone, two well marked horizons, are described and mapped in this report as Lorraine.

The formation consists chiefly of alternating thin bedded shales and sandstones together with some thin layers of limestone. There is no sharp line of separation between the Utica and the Lorraine, the lowermost shale beds of the Lorraine being in every way like those of the Utica. The lower Lorraine, comprising a thickness of approximately 200 feet of shales, is not very fossiliferous and contains occasional thin beds of fine grained sandstone. Among the fossils the Endoceras proteiforme and Triarthrus becki, so common in the Utica shale, are also found here. The lower Lorraine as thus described corresponds in a general way at least to Vanuxem's Frankfort slate and sandstone.[1]

The upper Lorraine, showing a thickness of something over 400 feet, is made up of gray, fine grained sandstone beds alternating with black to dark gray shales and occasional thin beds of impure limestone. Passing upward the sandstone content increases greatly and the thin partings of shale become rather sandy and light colored. The upper Lorraine sandstones and limestones are highly fossiliferous and fragments of sandstone full of fossils are strewn over the Tug hill region in great quantities. Among the many fossils some of the more noteworthy forms are: Pentacrinites hamptonii of the echinoderms, Leptaena sericea and Orthis testudinaria of the brachiopods, Ambonchyia radiata and Modiolopsis modiolaris of the lamellibranchs and Cyrtolites ornatus of the gastropods. A more complete list of fossils for this general region may be found in a paper by Walcott.[2] The upper Lorraine as here described corresponds roughly to the sandstone shale of Pulaski as used in Vanuxem's report.

From the standpoint of both areal extent and thickness the Lorraine is the principal Paleozoic formation of the quadrangle. Except for the small Oswego sandstone area, the Lorraine occupies all of Tug and Mohawk hills. Fine sections are exposed along the larger streams which cut across the eastern front of Tug hill, the best one probably being in Whetstone gulf [*see* pl. 9]. The whole thickness of the formation is shown in the township of Turin where it is estimated at 630 feet. About 600 feet are shown in Mohawk hill with the top not present. Well records to the west and south

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[1] *loc. cit.* p. 61.

[2] Geol. Soc. Am. Bul. 1890. 1:348-49.

show the Lorraine to be 600 feet thick at Lorraine (Jefferson co.); 530 feet at Stillwater (Oswego co.); 549 feet at Central Square (Oswego co.); 640 feet at Chittenango (Madison co.) and 720 feet at Vernon (Oneida co.). According to these figures there is somewhat of variation in thickness but not in any particular direction.

Oswego sandstone

This formation is so named because of its prominence in Oswego county. It is the only representative of the Upper Siluric within the quadrangle, and corresponds to the gray sandstone of Oswego as used in Vanuxem's report. But one small area occurs within the map limits and this forms the capping of the highest part of Tug hill. This area represents the easternmost extension of the formation which occupies many square miles in the southern part of Lewis county. The Highmarket quadrangle, immediately to the west, is literally strewn with slabs of this sandstone and the region is characterized by numerous swamps and a sluggish drainage.

Within the map limits the Oswego sandstone is a gray, fine grained, thin bedded rock. The stratification is not very regular and practically no shale is present. Fine examples of cross-bedding on a small scale are common. A characteristic feature is the presence of occasional yellowish spots of limonite, which are no doubt due to the alteration of original iron pyrite. In marked contrast to the underlying formation, the rock examined appeared to be barren of fossils. The sandstone lies between the 2000 and 2100 foot contours, thus showing a thickness of about 100 feet but with the top not reached.

STRUCTURAL GEOLOGY

Dip of the Paleozoic formations

Movements since the deposition of the Paleozoic strata have given them a very perceptible dip toward the southwest. This dip may be determined, in a general way at least, by comparing the altitudes of given horizons within the Port Leyden quadrangle and south and west. For this purpose the top of the Trenton is chosen because it is so clearly recognized in well sections.

The top of the Trenton in the Rome well, as reported by Prosser,[1] is 205 feet below sea level, while 2 miles west of Port Leyden it is

[1] Am. Geol. 1900. 25:137.

1280 feet above sea level. Thus in a distance of 25 miles the top of the Trenton drops 1485 feet or shows a southerly dip of nearly 60 feet per mile.

According to Orton,[1] the top of the Trenton in the Central Square (Oswego co.) well was struck at 1209 feet below sea level. The same horizon 2 miles west of Port Leyden is at an altitude of 1280 feet above the sea which thus shows an increased elevation of 2489 feet within 44 miles or a southwesterly dip of over 56 feet per mile.

In the Stillwater (Oswego co.) well Orton[2] reports the surface of the Trenton at 25 feet below sea level and this is 1305 feet below the same horizon 2 miles west of Port Leyden. The distance is 30 miles and the westward dip is over 43 feet per mile.

Within the map limits, near Locust Grove, the Trenton-Utica contact is at an elevation of nearly 1300 feet, while 2 miles to the southwest it is a little over 1100 feet, thus indicating a southwestward dip here of about 50 feet per mile.

An exceptional dip of 3 or 4 degrees toward the southwest may be seen in the Trenton limestone in the vicinity of Martinsburg. This is probably due to the updrag effect of the fault below described.

Faults and folds

No fault of sufficient extent to be mapped has been found within the limits of the quadrangle. A few places have been noted where there have been slight movements of 1 or 2 feet as for example in the Trenton of the Black river gorge 2½ miles northeast of Boonville.

Just beyond the edge of the map and in a ravine ¾ of a mile northwest of East Martinsburg station a fault with considerable displacement is well shown. No detailed study of this fault has been made, but it is of the normal type and strikes approximately northwest-southeast. Its length was not determined. The fault plane stands nearly vertical and the limestone beds are highly inclined on the south side as a result of the updrag during the process of faulting. On the north side of the ravine the Precambric lies fully 40 or 50 feet higher than on the south side and this represents the amount of the throw. The Pamelia beds have been faulted against the Precambric. The unusually rapid downward slope of

[1] N. Y. State Mus. Bul. 30. 1899. p. 455.
[2] *loc. cit.* p. 448.

the Precambric surface between Glenfield and East Martinsburg is due to the settling of the mass on the south side of the fault.

Extensive folding of the Paleozoic rocks nowhere occurs. Local folds are sometimes developed but even these are rare. Such small folds are best seen ½ mile above the mouth of Mill creek (north of Boonville); near Denley; and where the railroad crosses Sugar river. At the latter place a syncline in the Trenton is perhaps the best example of folding in the district.

The folded structure of the Precambric rocks will be dealt with under the heading "Gneissic structure."

Ripple marks

Small ripple marks are frequently present in the Paleozoic formations. Thus at several horizons within the Pamelia, Lowville and Trenton limestones there are ripple marks which measure 1 or 2 inches from crest to crest and about ½ inch from trough to crest. Special attention, however, is called to certain ripple marks of unusual interest in the Trenton. They are of unusual interest both because of their large size and their occurrence in limestone. These marks occur about 25 or 30 feet above the base of the Trenton and are finely shown in the south bank of Sugar river a short distance above the railroad bridge. The ripples measure from 24 to 56 inches from crest to crest, and 4 to 7 inches from trough to crest. They strike about n. 30° e. The ripple marked layer varies in thickness from 2 to 9 inches and is a crystalline and very fossiliferous limestone. Shale occurs immediately above and below the marked stratum and the shale above thickens or thins according to whether it rests upon the troughs or crests of the ripples. The limestone layers both above and below rapidly thicken and thin and are certainly of shallow water origin.

Gneissic structure

The precambric rocks, which are metamorphosed, igneous and sedimentary masses, all exhibit the gneissic structure. This structure is best developed in the old Grenville sediments and least in the syenite. In the areas of mixed gneisses it is also clearly shown. The strike of the gneissic bands varies from north-south to almost east-west, but the most common range is from n. 40° to 70° e. The direction of dip of the foliation planes is either northward or southward but prevailingly northward. The angle of dip is usually high, varying from 50 to 80 degrees although just north of Lyons

Falls it is as low as 20 or 25 degrees. From south of Denley to 3 miles north of Lyons Falls the dip is northward; thence northward to just south of Glenfield it is southward; thence northward to the map limit it is northward. Thus we have good evidence of distinct folding of the Precambric rocks on a large scale. Certain other Precambric rock structures will be discussed later.

Structure sections

The structure sections shown in figures 2–4, page 38, have been carefully chosen with the idea of giving the best general notion of the various rock formations and their relationships to each other.

PALEOZOIC OVERLAP

It is well known that during the general subsidence (barring certain minor oscillations of level) of the Adirondack region in early Paleozoic times, sediments were being deposited on the Precambric surface and that these sediments gradually encroached upon the sinking land mass until nearly all, if not all, of the Adirondack region was covered by them. The younger formations extended farther in than the older ones upon the sinking surface, thus constituting an overlap of the Paleozoic sediments upon the Precambric crystallines. The stripping off of this Paleozoic cover has been going on since the close of the Paleozoic era, at least, and the exposed surface of the Precambric rocks is still being enlarged by this same process. A glance at the structure sections [fig. 2–4] will show the eroded edges of about 1500 feet of sediments which formerly must have extended farther eastward upon the Precambric surface. In the Port Leyden district we have positive evidence to prove the Paleozoic overlap.

On the western side of the Adirondacks the oldest overlapping formation is the Potsdam sandstone. It is not present in outcrop within the Port Leyden quadrangle, the nearest exposures being about 20 miles northward in the vicinity of Carthage. According to Orton[1] the Potsdam, resting upon the Precambrics, occurs in Oswego county to the west and southwest of Port Leyden as shown in deep well sections. Thus the deep well at Central Square shows 156 feet of sandstone; the well at Parish 50 feet of sandstone and the well at Stillwater (southeast of Orwell) at least 49

[1] N. Y. State Mus. Bul. 30.

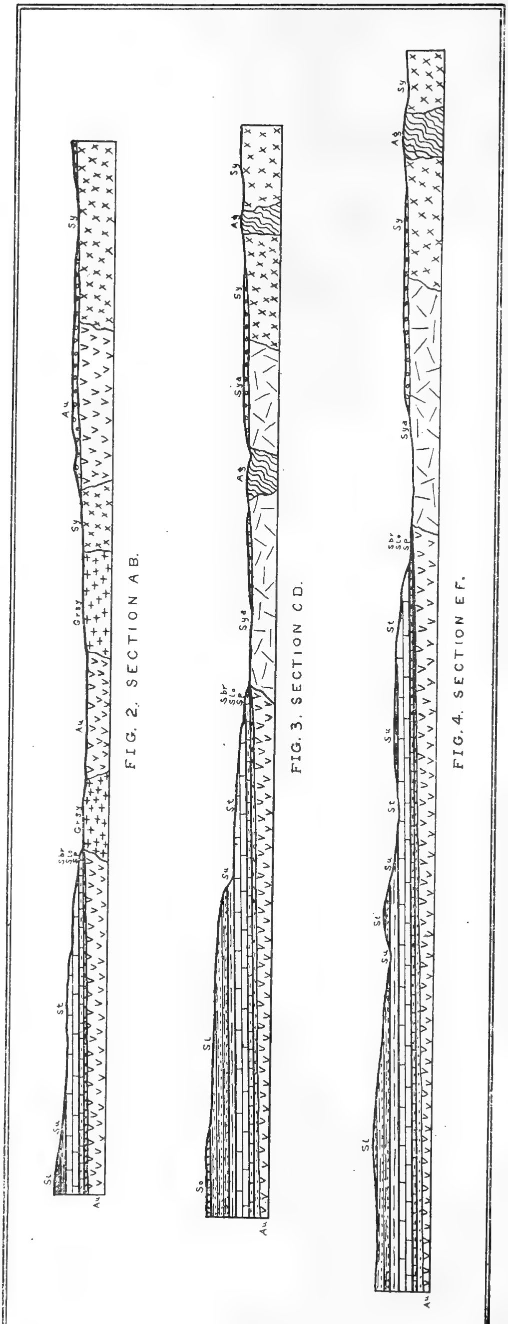

FIG. 2–4 Structure sections across the Port Leyden quadrangle. The section lines are indicated on the geologic map. The symbols are the same as those on the geologic map. Vertical scale is twice the horizontal.

feet of mostly sandstone. Orton refers all of these sandstones to the Potsdam. The bottom of the section at Stillwater is:

	Feet
Dark Trenton	370
Sand and shales	40
Sand, green and white	25
Black limestone	6
Red and white sandstone, calcareous	18
Precambric struck at	1697

Fossils in the black limestone layer prove the Upper Cambric (Potsdam) age of the deposit. The presence of this Potsdam in Oswego county and its absence along the Paleozoic-Precambric boundary to the eastward on the Port Leyden sheet, affords conclusive evidence of overlap.

Again, we have a strong argument in favor of overlap if we consider the whole thickness of sediments between the top of the Trenton and the Precambric. Details will be presented later, but suffice it to say now that a comparison of the thickness of these sediments in Oswego county with those near Port Leyden shows a thinning of several hundred feet in passing toward the latter place. Such a marked diminution in thickness toward the northeast and east is just what would be expected in the case of overlap.

SURFACE OF THE PRECAMBRIC ROCKS

Smoothness of the surface which received Paleozoic deposition

A study of the Paleozoic-Precambric line of contact gives strong evidence in favor of the statement that the sinking surface which received Paleozoic sedimentation must have been worn down to a remarkably smooth condition (peneplain). Except for a few miles near the southern edge of the map, the Paleozoic-Precambric boundary line can be drawn with a considerable degree of accuracy. A glance at the geologic map will show that this boundary line is a very regular one which at no point shows any rapid elevation or depression. Such a regular line of contact is precisely what one would expect where sediments have been laid down upon a smooth floor and then, after elevation, have been stripped off rather regularly by erosion. Even a comparatively small elevation or depression along the contact line could be recognized. At several points where the actual contact is exposed, the Precambric floor appears to be smooth.

Because of the deep mantle of sand and gravel which now covers the Precambric surface east of Black river, the configuration of that surface can not be studied to the best advantage. But so far as can be judged, if the stream channels in the Precambric surface were filled up the resulting surface would be comparatively smooth and even which strongly argues for that sort of a surface before the stripping off of the sediments and later erosion. Any prominent elevations on the old floor ought now to be recognizable, especially in the valley bottom and near the Paleozoic boundary, but none occur there. The distinct rock ridge southeast of Fowlersville seems to be the only example of such an elevation. This ridge rises about 80 feet above the general level but its hight is thought to have been somewhat accentuated by ice action. Again, if there had been any marked depressions in the old floor they would have been filled up with Paleozoic sediments and we might well expect to find such protected sediments as isolated patches or outliers within the general Precambric area as, indeed, the Potsdam sandstone does occur some 30 or 40 miles farther northward. The available evidence, however, points to a complete removal of the sediments.

The conclusion for the Port Leyden quadrangle is that the Precambric floor upon which the sediments were laid down was comparatively smooth and even, with only one known elevation rising above the general level. This is substantially the conclusion reached by Professor Cushing and the writer for the Little Falls and Remsen quadrangles respectively and it is true of the southern and southwestern border of the Adirondacks. This result as Cushing says "seems specially important in view of the fact that Professors Kemp and Smyth, and the writer (Cushing) also, have found evidence to show that, in the St Lawrence and Champlain valleys and vicinity, the surface on which the Potsdam was deposited was considerably more uneven than this. In other words, the surface to the south was worn down to a nearer approach to base level than was the case farther north."

Slope of the Precambric surface where now exposed

We have just shown that the Paleozoic sediments were deposited upon a very smooth Precambric surface. The uneven and dissected character of that surface where now exposed is due almost entirely to erosion since the stripping away of the sediments. A fairly good idea of the present general slope of this surface may be obtained by comparing altitudes at various points.

Near Partridgeville the Precambric lies at about 1300 feet above the sea level, while at Hawkinsville (Boonville sheet), 16 miles southward, it lies at 1060 feet. The difference in elevation is 240 feet or the slope per mile southward is 15 feet between these places.

One mile south of Donnattsburg the Precambric is at 1020 feet, while at Port Leyden, 10½ miles southward, its elevation is 900 feet. The difference in elevation of 120 feet shows a southward slope of over 11 feet per mile in this direction.

The Precambric near Partridgeville is at 1300 feet, while just west of Glenfield, 7½ miles westward, it lies at 840 feet. Thus we get a difference in elevation of 460 feet or a slope per mile of 61 feet toward the west. In a similar way we may find a slope, between Lyons Falls and a point east of Fowlersville, of 67 feet per mile westward.

In the vicinity of Woodhull lake, at the western edge of the Old Forge sheet, the Precambric elevation is 2000 feet while at Port Leyden, 17 miles westward, it is 900 feet. The difference in altitude is 1100 feet which means a westward slope of nearly 65 feet per mile.

These comparisons clearly demonstrate that the Precambric surface now slopes both southward and westward, but that the westward slope is much steeper. The writer has compared Precambric altitudes at many points over the Port Leyden, Remsen, Wilmurt and Little Falls quadrangles. The conclusion reached is that the exposed Precambric surface along the southwestern Adirondacks slopes both westward and southward; that the slope toward the west is steeper (being from 60 to 100 feet) than the slope toward the south (being from 11 to 50 feet); and that the general southwestward slope is greater in the Little Falls than in the Port Leyden region.

Slope of the Precambric surface where Paleozoics now cover

Having acquired some idea regarding the slope of the exposed Precambric surface it will now be of interest to determine the slope of the Precambric surface where Paleozoics now cover. This may be done by comparing altitudes of the Precambric within the Port Leyden quadrangle with the Precambric altitudes as found in certain deep wells to the south, southwest and west.

In the Campbell well 3 miles west of Utica, according to Prosser,[1] the Precambric was struck at 1500 feet below sea level, while at

[1] Geol. Soc. Am. Bul. 1893. 4:101.

Port Leyden it lies at 900 feet above sea level. The distance is 33 miles and the difference in elevation 2400 feet which shows a slope of over 72 feet per mile southward.

According to Orton,[1] the Central Square (Oswego co.) well shows Precambric at 2015 feet below sea level, while at Port Leyden its altitude is 900 feet. This shows a drop of 2915 feet in passing 46 miles southwestward or a slope of over 63 feet per mile toward the southwest.

In a deep well at Pulaski the Precambric was struck at 1048 feet below sea level, according to Orton.[2] Its altitude at Port Leyden is 900 feet, which indicates a drop of 1948 feet in a distance of 38 miles or a slope of over 51 feet per mile toward the west.

These results show that the Precambric slope under the Paleozoics is somewhat greater southward than westward and that the general southwestward slope is clearly less than it is in the Little Falls and the Remsen districts. Also the slope under the Paleozoics is greater than where no sedimentaries now cover, which is always true along the southwestern border of the Adirondacks. This is what would be expected because the general surface over the Precambric area has been reduced by erosion since the removal of the sediments. By referring to the above figures we find that if we consider a due east-west line through the Port Leyden district, the Precambric slope under the Paleozoics is actually a little less than it is east of them. This certainly means that the slope of the Precambric surface, before the removal of the sediments, must have been steeper eastward from Port Leyden than westward, and that it is still steeper in spite of the later erosion.

Slope of the Precambric surface during Paleozoic deposition

It is possible to get some idea regarding the slope of the surface upon which the older Paleozoics were being deposited by comparing the thickness of these formations with the same ones to the west and southwest in Oswego county. This comparison may be most satisfactorily made by considering together all of the deposits from the top of the Trenton to the Precambric, because in the well sections the different formations are not clearly distinguished.

In the well at Pulaski[3] the thickness of the strata from the top of the Trenton to the Precambric is 900 feet, while the corresponding

[1] *loc. cit.* p. 455.
[2] *loc. cit.* p. 489.
[3] *loc. cit.* p. 489.

thickness just west of Port Leyden is only 500 feet. Between these places, which are 39 miles apart, the thickness has diminished 400 feet or at the rate of over 10 feet per mile toward the east.

At Central Square it is 806 feet from the top of the Trenton to the Precambric, while at Port Leyden it is 500 feet. Thus in a distance of 45 miles the thickness has diminished 306 feet or at the rate of nearly 7 feet per mile toward the northeast.

In the Stillwater well the top of the Trenton lies 772 feet above the Precambric, while at Martinsburg it is about 600 feet. This shows a decreased thickness in 27 miles of 172 feet or at the rate of over 6 feet per mile toward the northeast.

Thus we see that there is an increasing thickness of these formations toward the southwest and west at from 6 to 10 feet per mile, and these figures may, in a general way at least, be taken to indicate the slope of the surface upon which the Paleozoic deposits were being laid down.

These results are significant when compared with the results similarly obtained by Cushing for the Little Falls district and by the writer for the Remsen quadrangle. In the Little Falls region the slope receiving Beekmantown deposition was about 30 feet per mile southward; while in the Remsen district the slope receiving Trenton deposition was from 6 to 20 feet per mile southwestward, the greatest slope being in the southeastern portion of the district. Thus it is pretty well established that the slope of the surface receiving Paleozoic deposition was very considerably greater in the vicinity of Little Falls than in the vicinity of Port Leyden and that there was a gradual change from the steeper to the more nearly level surface.

The results obtained for the Port Leyden quadrangle are also significant in another way. The thickness of the formations here, from the top of the Lorraine to the Precambric, is approximately 1400 feet. This thickness is great enough so that even after allowing for decreased thickness due to overlap and a possibly increased slope (receiving sediments) as the heart of the Adirondacks was approached, we seem to have here a strong argument in favor of the submergence of the region for many miles to the east and northeast of Port Leyden, so that by the close of the Lower Siluric the submergence extended to, or close to, the heart of the Adirondacks. This conclusion is quite different from that reached by Cushing by similar reasoning for the southern Adirondacks. He says:[1] "This line of evidence would therefore, so far as it may be worth anything,

[1] N. Y. State Mus. Bul. 77. 1905. p. 61-62.

seem to indicate that the southern Adirondack region could not have been completely submerged at the close of the Lower Silurian, much less so at the close of the Trenton."

PLEISTOCENE (GLACIAL) GEOLOGY

From the standpoint of its glacial history the Port Leyden district is unusually interesting and instructive. When the great ice sheet, which covered most of New York State, reached its maximum development the Black river valley must have been buried under several thousand feet of ice. We know this because the whole Adirondack region is glaciated and was covered by the ice. The advance and retreat of the ice across the Port Leyden quadrangle has left most of the ordinary marks of glaciation, while certain of them are developed to a remarkable degree. So far as the writer knows nothing has been published regarding the Pleistocene history of this immediate region, although a report by Chamberlin[1] published some 27 years ago has an indirect bearing.[2]

Direction of ice flow

Chamberlin, in the report above referred to, makes the tentative statement "that massive ice currents having their ulterior channels in the Champlain valley, on the one hand, and the St Lawrence on the other, swept around the Adirondacks and entered the Mohawk valley at either extremity, while a feebler current, at the hight of glaciation, probably passed over the Adirondacks and gave to the whole a southerly trend." Observations by later investigators have tended to bear out this view and the evidences from the Port Leyden quadrangle herewith presented have an important bearing upon the proposition.

The direction of flow is best shown by the glacial striae which have been observed at a number of different places through the district. The striae are best preserved upon the hard Precambric rocks, but these are mostly drift covered except along the chief stream courses. The limestones are next most favorable while upon the shales none have been found. Striae are present only upon those surfaces from which the drift has been recently removed, because

[1] U. S. Geol. Sur. 3d An. Rep't 1881–82. p. 360–65.

[2] Since the above was written Prof. H. L. Fairchild has presented several papers, bearing on the glacial history of northern and central New York, before the 1908 meeting of the Geological Society of America. These papers will be published in the bulletin of the society

even the hardest rocks, exposed during all of postglacial time, have been weathered enough to cause an obliteration of the glacial marks.

Striae pointing from s. 25° to 40° e. have been located as follows: On Trenton limestone 1 mile south of Martinsburg and also ⅓ mile to the east of that village (s. 25° e.); on Black River limestone just west of Lyons Falls; on Precambric near the mouth of Roaring brook, 1½ miles northeast-north of Glenfield and also ⅓ mile southwest and ¾ mile southeast-south of the same village; on Precambric 1 mile northeast of Denley and ⅓ mile northeast of Hawkinsville. Striae bearing nearly south occur on the Precambric 1 mile east of Port Leyden. The southeasterly movement, shown by these marks, changed to a more nearly easterly movement in the Mohawk valley region, and this is just what would be expected according to the statement of Chamberlin. It should be noted that the Black river valley, which is the chief topographic feature on the western side of the Adirondacks, had much to do with determining the direction of flow of the ice. This valley existed in preglacial time and the close parallelism between the directions of the striae and the direction of the valley shows the influence of the latter in determining the ice movement. Along the northwestern border of the Adirondacks the ice undoubtedly moved southwestwardly. Along the eastern border of the Adirondacks the general southerly movement of the ice has been well established, as has also the westerly movement up the Mohawk valley toward Little Falls. Thus the statement of Chamberlin, regarding ice flow around the Adirondacks, harmonizes almost perfectly with the observed striae.

But the question still arises, what was the direction of the current during the hight of glaciation? We have abundant evidence to prove that, during the hight of glaciation, the main current was a southeasterly one. On the Long Lake quadrangle in the midst of the Adirondacks Professor Cushing has recorded a number of striae all of which point toward the southwest.[1] Over the region south of the Adirondacks and the Mohawk valley the observations of both Brigham[2] and Chamberlin[3] show that the ice moved in a general southwesterly direction. Another strong evidence favoring the southwesterly current is the distribution of glacial boulders over the

[1] N. Y. State Mus. Bul. 115. 1906. p. 495.
[2] Amer. Jour. Sci. 1895. 49:216.
[3] *loc. cit.* p. 365.

region southwest of the Adirondacks. Most of the common Adirondack rock types are strewn over the region and they gradually diminish in number as the distance from the mountains becomes greater. This subject has been discussed in a paper by Brigham.[1]

Thus, bearing in mind all the facts, the writer is strongly of the opinion that when the ice in its southward movement struck the Adirondacks, it was divided into two currents flowing around the mountains and meeting in the Mohawk valley; that during the time of maximum glaciation there was a strong general southwesterly current, but that the border currents continued as under currents (more or less checked in velocity); and that after the disappearance of the ice sheet from the central Adirondacks, border currents were maintained. According to this the Port Leyden quadrangle was first invaded by a tongue of ice which flowed southeastward up the Black river valley. When the general ice sheet had here reached a thickness of several thousand feet the main current was southwesterly, but with a southeasterly under current in the valley bottom. The ice first melted from the highlands and left a tongue of ice in the valley which gradually melted and retreated northward.

ICE EROSION

Erosion of the Precambric rocks

As the ice moved across the quadrangle, the preglacial rock surface was more or less scratched, polished and eroded. In the case of the Precambric rocks it is doubtful if the ice did any very deep cutting. Its work of erosion involved mostly the removal of masses of decayed and weathered rock material near the surface. The evidence is conclusive that the weathered materials were rather thoroughly scraped off the Precambrics as shown by the remarkable freshness of the rocks wherever exposed and by the smoothed and rounded character of the outcrops [*see* pl. 3]. The highly jointed character of these rocks no doubt greatly aided the ice in its work of erosion. Mention should be made of the great number of erratics of Precambric rock material strewn over much of the region, especially toward the south. One of these erratics measures about 17 feet high and 27 feet across [*see* pl. 11]. The larger ones are mostly of the hard, homogeneous syenite or granite. Probably the greatest amount of erosion of the Precambrics occurred along Black river between Lyons Falls and Lowville, but this matter will be referred to below.

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[1] *loc. cit.* p. 213–28.

Erosion of the sedimentaries

Turning our attention to the sedimentaries, we find that ice erosion was much more effective upon them. In fact the writer believes that in the Black river valley we have one of the best examples of ice erosion in northern New York. One factor favoring the ice work here was the comparative softness and highly jointed character of the rocks, while another factor was their position with reference to the ice current.

The figure on page 48 shows the profile and geologic structure across the Black river valley 2½ miles north of Lyons Falls. One of the striking features is the terraced character of the sedimentaries, particularly from Port Leyden northward [*see* topographic map]. Along the river course there is a slight notch in the Precambrics and just west of this, on the northern part of the Port Leyden sheet, there is a steep slope rising 300 feet above the Precambrics. The formations outcropping on this slope are shown in the section. Resting upon the Precambrics are several feet of weak sandstones which are followed by the sandy limestones of the Pamelia; then come the hard Lowville and Black River limestones; while the summit is capped by hard, crystalline limestones. The streams passing over this slope are characterized by gorges with waterfalls and rapids. From the summit of this slope and extending for several miles westward there is a well defined terrace developed upon the limestone.

Rising from the western side of the above named terrace there is a second slope higher and much steeper than the first. The rise is commonly about 450 feet within ⅓ mile. The soft Utica shales outcrop at the base of this slope and they are followed by the Lorraine shales with an upward increasing sandstone content. The summit of this terrace, known as Tug hill, is more irregular and stream dissected than the limestone terrace below. All streams flowing across the steep slope of this terrace have high gradients and have cut deep, narrow gorges locally called "gulfs."

At first these terraces, in their present form, were thought to have been due entirely to water action, but an examination of the region shows that some other explanation must be sought. The steep fronts of the terraces are certainly young topographic features, which precludes the possibility of their having been formed during the long preglacial period of erosion in this ancient region. On the other hand, Black river has done very little work of erosion, between Lyons Falls and Lowville, in postglacial times as proved by the fact

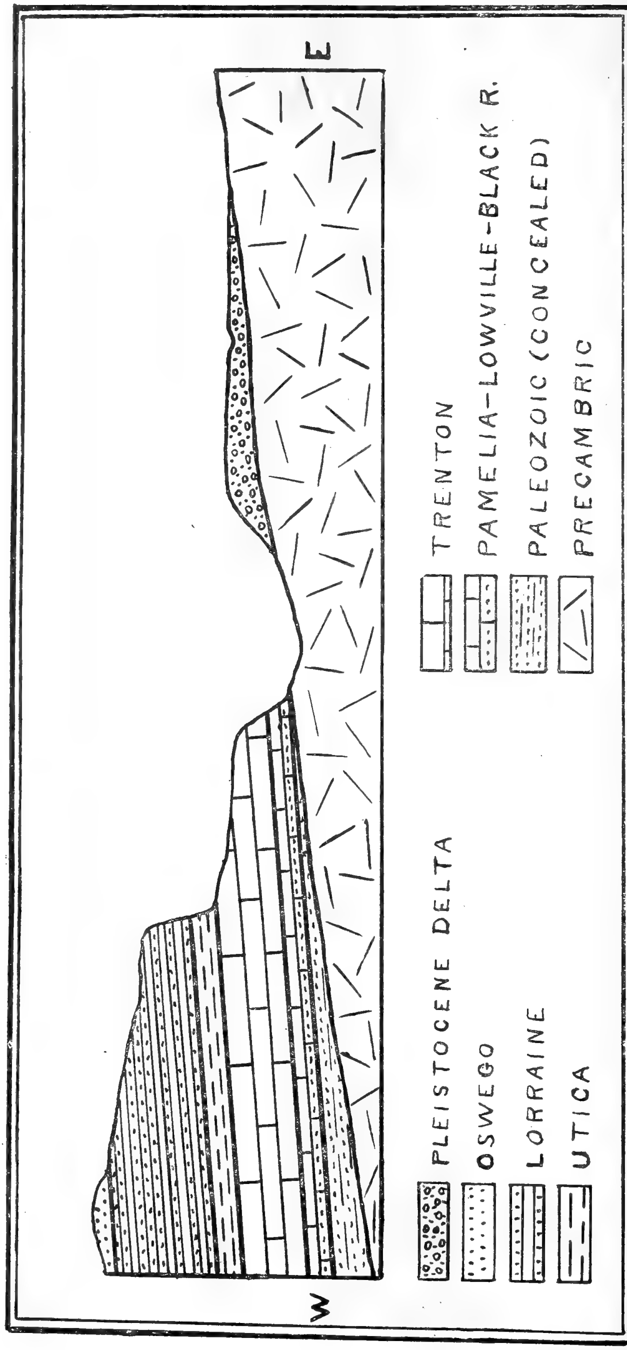


FIG. 5 East-west section across the Port Leyden quadrangle 2¼ miles north of Lyons Falls, showing the position of the delta deposits and the terraced character of the Paleozoic sediments. Vertical scale 8.8 times the longitudinal.

that the stream has not yet cut its way through the alluvium and reworked drift filling the valley bottom, and also because glacial striae and kames near the river level have not been disturbed. Thus also the slight trench cut into the Precambrics along here could not have been postglacial in origin.

There is still the possibility that glacial waters might have developed the terraces, but there is no evidence of any such vigorous water action especially along the higher part of the limestone terrace where records would surely be left. Even if a large stream had flowed along the ice edge and under the steep front of Tug hill its gradient would have been too low to be compatible with much cutting power. No doubt there was movement of water along the waning Black river ice lobe, but the only current of any importance was a northerly one between the eastern edge of the limestone terrace and the ice margin [*see* below]. The limestones here are somewhat water-worn, but the stream was about 200 feet below the top of the terrace and thus clearly could not have done the work of erosion over the whole terrace. Also the presence of glacial striae on the terrace shows that no great amount of erosion could have taken place there since the ice retreat.

It seems certain that the lowermost Paleozoic layers must have extended farther eastward, by overlap on the Precambrics, immediately preceding the glacial period. This means that Black river was some distance farther eastward and that the western tributaries from Tug hill entered it with lower gradients. As above shown, the lowest sedimentary beds could not have been cut back to form the steep slope now facing Black river in pre- or postglacial times nor were they cut back by glacial waters. Evidently they were cut back by the ice to develop the steep slope. This allowed Black river to shift westward to its present position. Thus the slight trench in the Precambrics here could not have been preglacial. As already shown it is clearly not postglacial and apparently it was formed by ice cutting. The concave character of this inner portion of the valley is brought out in the figure and strongly suggests ice work.

The fact should also be considered that we are here dealing with unaltered sedimentaries, with slightly upturned edges, resting upon a rather smooth surface of igneous and metamorphic rocks, and that the lowest sediments are weak sandstones and sandy limestones, which greatly favored the stripping off power of the ice. Robert

Bell[1] has noted similar conditions in Canada and he says that when the ice sheet moved from the crystallines against the edges of the unaltered sedimentaries "great erosion has always taken place and valleys and basins are formed whose width depends upon the angle of dip and the softness of the strata which have been scooped out. The strata are presented in the most favorable attitude for abrasion. The wearing down would go on till the resisting rock front had attained a hight and weight sufficient to counterbalance those of the glacier." In the Black river valley the ice moved from the crystallines against the slightly upturned edges of the sediments.

In much the same way the soft shales were stripped off the surface of the hard limestones to form the broad terrace and the steep front of Tug hill. Such a stripping off of the shales occurred, but to a less extent, over the southern part of the Port Leyden quadrangle and the western part of the Remsen quadrangle. The maximum thickness of shale thus removed was probably several hundred feet, but not over a wide area. The total amount of shale removed was not nearly as much as may at first sight be supposed. Then too the shales were soft and highly jointed even to a considerable depth as may now be seen in the Whetstone gulf section.

Two other factors which greatly aided the work of the ice in the Tug hill region must not be overlooked. One of these is the fact that the ice moved up hill as it advanced southward along the valley and so had its cutting power increased. On reaching the divide between Black river and West Canada creek the cutting power was lessened and till and other drift materials were deposited in great quantities as the ice moved down hill toward the Mohawk river. Another factor which the writer regards as important in this connection is the angle at which the ice current entered the Black river valley in its sweep around the Adirondacks. The greatest amount of erosion was along the eastern side of Tug hill, and it is just here where the ice current must have struck with greatest force as it crowded into the valley. In harmony with this idea is the fact that the glacial striae near Martinsburg bear more toward the south than does the steep front of Tug hill.

It may be fairly asked, what became of the materials thus removed? The very resistent Precambrics ought to be present in considerable force somewhere in the region as erratics and this is the case southward especially in the townships of Boonville and Remsen where vast numbers of such erratics may be seen. Shale

[1] Geol. Soc. Am. Bul. 1890. 1:296.

Plate 10

W. J. Miller, photo

Looking down Moose river from Goulds Mill. The river here, between Goulds Mill and Lyons Falls, flows through a drift-filled channel.

and limestone are also present in great abundance in the till and other drift of the Remsen quadrangle. However, much of the shale must have been ground up and carried away by glacial waters.

Glacial sand plains or terraces

A remarkable development of glacial sand plains or terraces is to be found within the Port Leyden quadrangle. Here, on the east side of the river, most of the region is occupied by these terraces, which taken together may be looked upon as a single great terrace with steep front facing Black river [*see* fig. 5]. On the Port Leyden sheet alone they cover fully 75 square miles and continue both northward and southward from this area. They are clearly shown upon the topographic map. The sands and gravels of these terraces show a depth of from 200 to 250 feet along the western edge, and there is a gradual thinning out to disappearance several miles eastward.

Except in a few cases the flat-topped surfaces are practically destitute of large boulders. A characteristic feature is the presence of pitlike or kettlelike depressions over the surfaces [*see* map]. These depressions are of various sizes and shapes and are sometimes occupied by lakes or ponds, as for example Brantingham, Little Otter and Catspaw lakes and Sand pond. They are often very steep-sided and range in depth from a few feet to 50 or 60 feet. The terraces are dissected by many streams so that enough good sections are exposed to make it certain that the materials are crudely stratified and cross-bedded, and occasionally interstratified with clay, thus proving that they were water laid. The western margin of this great terrace is distinctly lobate in character and is strongly suggestive of delta origin as for example in the southeastern part of the quadrangle. Another very notable feature is the concordance of altitudes at about the same distance back from the margin. The altitudes vary from about 1150 to 1260 feet, the higher altitudes being on the east, thus giving a gradual slope of the terrace surface toward Black river.

A study of the character and distribution of these terraces as well as their relation to the other drift deposits, leaves no doubt as to their origin as delta deposits in a marginal lake along the waning ice tongue during its retreat from the Black river valley. The immense amount of material thus deposited was readily obtained by the streams, especially Black and Moose rivers and Otter creek, as they emerged from the newly drift-strewn Adirondack highlands.

That they were deposited along the ice margin is clearly established by the presence of kames and large drift boulders along the western edge which prove an ice contact front here. The gradual downward slope of the sand plains toward the west is to be accounted for by the gradual lowering of the marginal lake level as the ice retreated.

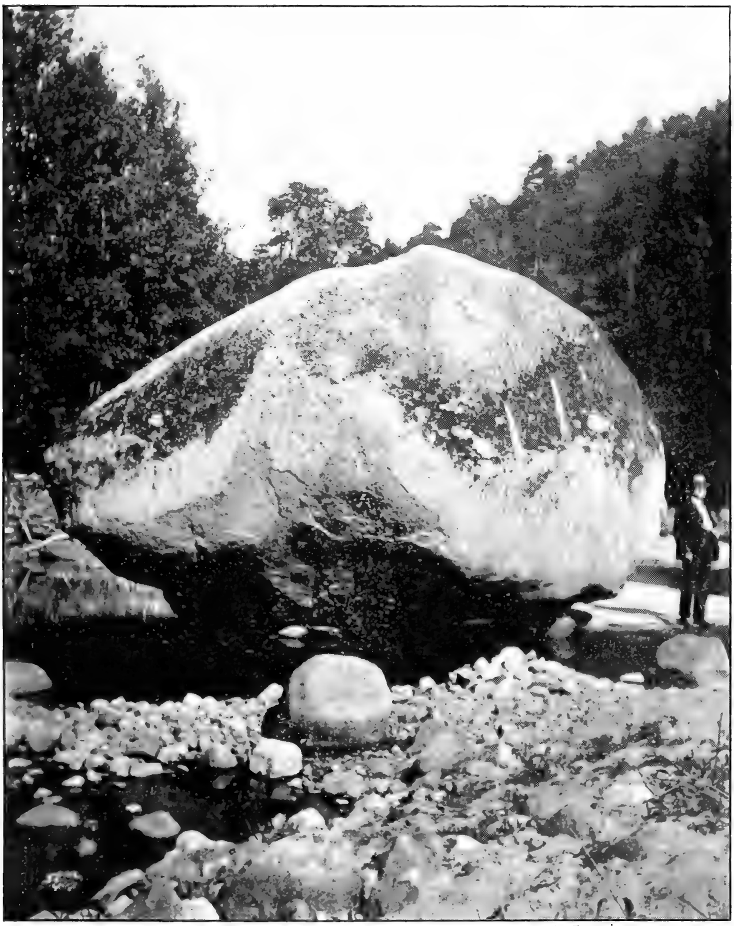
The depressions within the sand plains may be explained in either one of two ways. They may have been due to isolation of ice masses from the ice margin (possibly sometimes as icebergs) which were partially or completely buried under the delta sand to be melted later thus causing the development of the depressions, or they may have been due to unequal deposition of the delta materials whereby some places were not brought up to the general level. The depth, steepness of sides and irregular shapes of the depressions cause the writer to favor the first view to account for most of them.

Kames

Kames, which are hillocks of crudely stratified materials deposited at the ice edge, are rather abundantly represented except on the east side over the sand plain area. There is no group of large kames such as those of Park and Sperry hills within the Boonville quadrangle, or like those of the Remsen quadrangle described in a former report. Probably the best example of a single kame is the one ¾ of a mile southeast-south of Greig. It is remarkable for its steepness and symmetry of form and shows a hight of at least 150 feet. Many kames are located along the steep western front of the great sand terrace above described, especially from Lyons Falls northward. Other good examples may be found from south of Port Leyden to north of Lyons Falls along the railroad; south and west of Talcottville; along the road from Turin to Houseville; south and east of Martinsburg; and even on the highland southwest of Mohawk hill. Frequently, as in the locality last mentioned, there are long low ridges of stratified materials called eskers associated with the kames.

No doubt kames were also formed over the region now covered by the sand plains, but as the ice gradually retreated from the valley the kames formed along the ice edge were buried under the deep delta deposits. Only those along the western margin of the great delta deposit were left uncovered. Partially buried kames in the midst of a sand plain are finely exhibited around Forestport on the Remsen quadrangle. The sands are there comparatively

Plate 11



W. J. Miller, photo

An erratic or glacial boulder of syenite in the bed of Black river 2 miles northeast of Boonville. The boulder is about 27 feet across and 17 feet high and rests upon Black River limestone.

thin and after the formation of the kames and withdrawal of the ice edge, the delta sands were deposited around them but not with sufficient depth to cover them.

Erratics

Like the kames, glacial boulders or erratics are scattered over all parts of the quadrangle except the typical sand plains. Their absence from the sand plain belt is to be explained in much the same way as the absence of the kames, that is after the boulders were dropped by the melting ice they were covered by the delta deposits so that they are scarcely ever seen except along the larger stream courses where they have again been exposed by erosion. A good many are present along the western front of the delta terrace particularly in the vicinity of Greig. They are also strewn over the Paleozoic rock area, even on the high land of Tug and Mohawk hills.

The erratics are mostly from the hard, resistant Precambric formations and, as above pointed out, their presence on the high western portion of the quadrangle strongly argues for a southerly or southwesterly ice current at one time. The largest erratic observed by the writer is one of quartzose syenite, already referred to, which rests upon the Black River limestone about 2 miles northeast of Boonville. This boulder measures about 27 feet across and 17 feet high. Another large one may be seen in the field about ¾ of a mile east-northeast of Denley station.

Glacial lakes

A very interesting and extensive glacial lake occupied all of the sand-flat country on the east side of Black river between Forestport and Lowville. It also extended somewhat west of Black river in the vicinity of Boonville, and to an unknown distance north of Lowville. The former presence of this large lake is conclusively shown by the great development of unquestioned delta deposits, associated with clays, and the remarkably concordant altitudes of the sand plains [*see* above]. These waters were impounded by the waning lobe of ice in the Black river valley. The kames and drift boulders along the western edge of the great delta deposit show an ice contact from there; also the absence of delta deposits on the west side of the valley, under Tug hill, shows that the lake did not extend that far west. Again the failure of any delta deposits to reach out to or across the valley bottom also argues for ice occu-

pancy of the deepest part of the valley during the existence of the large lake. In his description of the deposits along the Connecticut river, Gulliver has noted similar features and argues that those deposits must have formed before the ice had completely melted from the valley.[1]

The highest water level in this lake was apparently something over 1300 feet at which time an outlet probably crossed the Black river-West Canada creek divide[2] near Honnedaga (Remsen sheet) and flowed southward toward Trenton Falls. Possibly the extensive sand deposits near the latter place were formed by this outlet, although West Canada creek may have contributed to their formation. Further retreat of the ice lobe down the Black river valley certainly opened an outlet southwestward past Boonville and down Lansing kill toward Rome causing deposition of the great delta deposits north of the latter place. This delta no doubt formed in Lake Iroquois or rather its broad outlet in the Mohawk valley. This outlet from the glacial lake affords a fine example of a " through valley " to use the term suggested by Davis. The preglacial divide was doubtless near Hurlbutville as shown by the widening of the channel both northward and southward from that place; by the existence there of a deep inner gorge; by the aggraded stream bottom north of Hurlbutville; by the fact that the present stream could not have cut the deep narrow channel north of Hurlbutville and by the right elevation of an outlet there. The lake stood at approximately the 1250 foot level when it started over this divide and it cut down the divide rapidly until the 1140 foot level in the lake was reached. By this time the ice tongue had so far melted as to allow an escape of the water northerly and northwesterly along the west side of the ice tongue and into Lake Iroquois near Watertown. These north moving waters have left the limestones just west of the river more or less waterworn and possibly some of the minor terraces were formed by them.

Another lower and very distinct lake level was a little below 800 feet and caused by still further ice retreat to allow an accumulation of water back of a barrier at Carthage. The river is still engaged in cutting through this barrier. This lake extended southward to Lyons Falls where it was very narrow. Between Lyons Falls and Carthage the river now shows a very low gradient and the winding

[1] Am. Geol. Soc. Proc. 1907. 18:640.

[2] The rather recent land movements in the region are not considered. Thus the elevations given are comparative only, but they are not far from the actual lake levels which were doubtless lower.

stream is developing terraces through the old lake deposits of the valley bottom.

Drainage

Black river and its tributaries. From Hawkinsville to opposite Denley, Black river is certainly out of its preglacial channel as shown by the gorge cut into the limestones. Its former course was probably about 2 miles eastward along the Paleozoic-Precambric boundary. Between Denley and Port Leyden it is practically in its old channel. Thence to east of Lowville the stream is somewhat west of the preglacial course due to the westward shifting of the Paleozoic-Precambric boundary by erosion during glacial times. It is doubtful if any of the tributaries of Black river, which cut through the delta deposits and into the Precambrics, follow their old channels because they have been superimposed upon the Precambric surface. Thus Moose river has cut through the deep sands and is now engaged in eroding a channel, with gorges and waterfalls, into the Precambrics.

Origin of the "gulfs." The deep gorges which have been cut through the steep eastern front of Tug hill, by tributaries of Black river, are locally known as "gulfs." The chief gorges are occupied by Mill, House, Whetstone and Atwater creeks and Roaring brook. Whetstone gulf which is perhaps the most interesting, is about 2 miles long and shows a depth of 300 feet [*see* pl. 9]. Its walls are very steep sided to almost vertical, especially in the upper end (narrows) where there is just room enough for the stream at the bottom and where erosion is now proceeding most rapidly. A section showing something like 700 feet of Lorraine and Utica shales is finely exposed in this gorge. The stream emerges from the "gulf" upon the broad limestone terrace.

During glacial times the shales were eroded back over the limestone for a considerable distance, and this caused the development of the steep eastern front of Tug hill. After the disappearance of the ice from the region, all of the east bound streams from Tug hill rushed over this steep slope and began to erode notches into its summit. These notches were rapidly deepened in the soft shales to develop the "gulfs," whose heads have since been cut back to their present positions. South of Tug hill the "gulfs" are not so well developed because the shales, with their preglacial channels, were not cut back by erosion to such a great extent.

ECONOMIC PRODUCTS

Soils

The principal industry of the region is farming and the success of that industry here, as elsewhere, depends not only upon the character and energy of the people, but also, to a large extent upon the nature of the soil. The Port Leyden quadrangle affords us a fine example of the dependence of agriculture upon the geologic formations. From the standpoint of fertility of soil, Black river divides the district into two portions which present a remarkable contrast. Eastward from the river the territory is mostly covered with deep sands and gravels which are generally unproductive. Occasionally along the stream bottoms or where some clay is mixed with the sand, the soil is of fairly good quality. The potato crop is best suited to this sandy soil. There are many deserted farms on this side of the river and apparently this section was most prosperous when lumbering was the chief occupation of the people and farming a secondary matter.

On the west side of the river where the geologic formations are chiefly limestones and shales, and where sands and gravels are sparingly present, there is a prosperous farming community. Here the surface is mostly strewn with glacial debris which is largely composed of ground up shale, sandstone, and more or less limestone, which is thus a rich and easily worked soil.

Building stone

Building stone of fine quality occurs in immense quantities within the map limits. The rocks most quarried for this purpose are the limestones of the Pamelia, Lowville and Black River formations, but especially the Lowville. Many large quarries have been opened up in these formations, the principal ones being located on the geologic map. Such stone was used in building the numerous locks of the Black river canal and then later by the railroad for bridge abutments. It now has a considerable local use, especially for foundations. The highly jointed and stratified character of the Lowville and Pamelia beds cause it to be readily accessible in layers of almost any desired thickness up to about 2 feet. The Lowville is a bluish gray, very fine grained, pure limestone, while the Pamelia is usually a whitish gray to pink, more or less sandy and impure limestone. The gray Black River limestone quarries out as

a more massive stone. The most extensive quarries are between the mouth of Sugar river and Denley station.

Other good building stone is found in the Trenton limestone, especially the upper portion. This rock is gray, coarse grained, crystalline, and pretty pure and may be quarried in layers from a few inches to a foot thick. The stone is much used locally and was formerly burnt in great quantities for the production of lime. The chief quarries are at Talcottville, Turin and Martinsburg. The sandstones of the upper Lorraine are strewn over the highlands on the west and are of considerable local use.

Of the Precambric rocks, the syenite is an excellent building material. It is a very hard, greenish to reddish, rather granitic syenite which takes a high polish. The expense of quarrying and transportation have almost entirely prevented its exploitation. A quarry from which syenite of fine quality has been taken is located about a mile east of Denley station.

Road materials

Most of the Precambric rocks, but especially the syenite, because of its great durability, when crushed would yield excellent road materials. Most of the stone now used for road work comes from the Lowville and upper Trenton limestones because this stone is cheaply quarried and crushed and is fairly durable.

Sand and gravel

As above explained much of the country east of the river is deeply covered with sand and gravel, often of good quality for all sorts of uses. The increasing demand for such materials will, in the future, doubtless cause the exploitation of these immense deposits.

Iron ore

In the above descriptions of the Precambric rocks, magnetite, in small grains, is seen to be very commonly present. Many times patches of magnetite 1 or 2 inches across have been observed in the mixed gneisses and in the more acid phases of the syenite and they have every appearance of being segregation masses. An ore body several feet across has been found on the Murtaugh farm 2 miles east of Glenfield. It is magnetite mixed with much pyrite and is closely associated with pegmatitic material in the granitic syenite. The pegmatite and ore seem to grade into the country rock and probably represent a segregation mass.

The most interesting and important magnetite deposits occur in the village of Port Leyden and on the west side of the river below the bridge. Many years ago several attempts were made to mine the ore here. An ore pit, now filled with water, was run down some 50 or 60 feet and a furnace was erected, but the mine was never a paying proposition. Ore was later brought to the furnace from other places. The ore is magnetite associated with much iron pyrites and often with quartz. A thin section of the ore from the pit shows 50% of quartz; 45% of magnetite and pyrite and 5% of badly decomposed ferro-magnesian minerals. The wall rock from the pit shows 35% of feldspar, chiefly microperthite and some oligogclase; 45% of quartz and 20% of biotite, pyrite, sillimanite, zircon and garnet. Thirty feet from the ore pit, the feldspar content is somewhat higher and the dark minerals not so prominent. Still farther away the rock is much like a quartzose syenite. A few rods from this pit and at the water's edge, an irregular shaped ore body several feet across may be seen. It is nearly pure magnetite and entirely surrounded by syenite. The ore is in no sense sharply separated from the country rock. A rapid but perfect gradation of the ore into the syenite may be seen and the evidence seems conclusive that this small ore body, at least, is a segregation mass in the syenite. The ore in the pit is thought to have a similar origin, although the evidence is not there quite so conclusive. This ore is closely associated with syenite and garnetiferous gneisses in a syenite-Grenville area and it is interesting to note that the Salisbury Iron Mine described by Cushing on the Little Falls quadrangle, and the occurrences noted by the writer on the Remsen quadrangle, all show similar relationships to the country rock. It would seem that when the molten syenite was passing through the Grenville the conditions were somehow made favorable for the segregation of the magnetite.

Lead ore

Before the middle of the last century lead ore was discovered in the Trenton limestone about a mile a little west of north of Martinsburg. The early attempts to mine the ore and extract the metal failed because of the small quantity of ore available. The ore is galena (sulphid of lead) which occurs in true vein deposits and associated with calcite as a gangue material. The calcite is frequently crystallized in six-sided prisms capped by three-sided pyramids. The vein-stuff fills joints in the limestone and the galena has doubtless been dissolved out of the surrounding rock and deposited in the veins.

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Education Department Bulletin

Published fortnightly by the University of the State of New York

Entered as second-class matter June 24, 1908, at the Post Office at Albany, N. Y., under the act of July 16, 1894

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New York State Museum

JOHN M. CLARKE, Director

Museum Bulletin 137

GEOLOGY OF THE AUBURN-GENOA QUADRANGLES

BY

D. D. LUTHER

New York State Education Department
Science Division, October 23, 1909

Hon. Andrew S. Draper LL.D.
Commissioner of Education

SIR: I have the honor to communicate herewith for publication as a bulletin of the State Museum, geological maps of the Auburn and Genoa topographical quadrangles, with the necessary explanatory matter pertaining thereto.

Very respectfully
JOHN M. CLARKE
Director

State of New York
Education Department
COMMISSIONER'S ROOM

Approved for publication this 25th day of October 1909

A. S. Draper

Commissioner of Education

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GEOLOGY OF THE AUBURN-GENOA QUADRANGLES

BY

D. D. LUTHER

INTRODUCTION

The area embraced within the Auburn-Genoa quadrangles lies between the lines of 42° 30' and 43° north latitude and 76° 30' and 76° 45' west longitude and contains 455 square miles.

The waters of Cayuga lake cover 65 square miles of this area, Owasco lake 10 square miles and the alluvium along the Seneca river 6 square miles, while about 50 square miles in the towns of Montezuma, Aurelius, Throop and Sennett are a low lying region where no outcrops of bed rock occur but the surface is highly diversified by the large number of lenticular hills or drumlins into which the heavy drift sheet is arranged.

These drumlins, the more prominent of which are 100 to 150 feet in hight and usually many times longer than wide, rise quite abruptly at the north ends and extend in a generally south-southeast direction, gradually diminishing in size. The contour lines of the map indicate the position of more than 60 drumlins in characteristic shape and 100 feet or more in hight, while many others are equally well defined, though less prominent. The region in which these occur is a small portion of the New York drumlin area which covers 2500 square miles and is estimated to include 10,000 drumlin crests. The drumlins of central western New York have been described by Prof. H. L. Fairchild in State Museum Bulletin 111.

The south edge of the drumlin belt is along the foot of the Helderberg limestone escarpment which extends across the Auburn quad-

rangle from the northeast corner in a southwestern direction to Cayuga lake at Union Springs. Over most of this higher ground south of this limestone escarpment the drift sheet is quite thin, probably something less than 20 feet on the average, but it is gathered in many places into hills of a drumlin character, and, in a few instances in the vicinity of the foot of Owasco lake, into well defined drumlins. The remaining portion of the area included within the limits of these quadrangles is on the sloping sides of the Cayuga lake, Owasco lake and Salmon creek valleys where there are numerous ravines, some of which are large and afford fine rock exposures. The rocks are finely and accessibly displayed by nearly 50 miles of cliffs along the lake shores.

These favorable conditions for the study of the stratigraphy and paleontology of this section of central New York and the easy accessibility of the region, led to its early investigation and description by Vanuxem and Hall, while engaged on the Geological Survey of the third and fourth districts, and have made it classic ground to students of those sciences in later days.

The following geologic formations are represented by colors on the map of the Auburn-Genoa quadrangles in descending order:

Devonic	Senecan	West Hill flags and shales
		Grimes sandstones
		Hatch shales and flags
		Cashaqua shale
		West River shale
		Genundewa limestone
		Genesee black shale
		Tully limestone
	Erian	Moscow shale
		Tichenor limestone
		Ludlowville shale
		Skaneateles shale
		Cardiff shale
		Marcellus black shale
	Ulsterian	Onondaga limestone
	Oriskanian	Oriskany sandstone
Ontaric or Siluric	Cayugan	Manlius limestone
		Rondout waterlime
		Cobleskill limestone
		Bertie waterlime
		Camillus shale

The 21 geologic units into which the surface rocks of these quadrangles are divided have an aggregate thickness approximately of 1920 feet, of which 1080 feet appear in ascending from 380 A. T. in the northwestern corner of the Auburn quadrangle to 1460 A. T. in the southwest corner of the Genoa quadrangle and 840 feet are brought up by the northward elevation of the strata at an average of about 25 feet per mile for the whole distance, though the dip is extremely variable and for a few miles in the southern part of the Genoa quadrangle actually reversed.

FORMATIONS IN ASCENDING ORDER

SILURIC

Camillus shale

This formation is that subdivision of the Salina group which, along the line of outcrop, succeeds the red Vernon shale and at or near the base of which the New York rock salt beds are reached in the deep borings at Tully, Ithaca, Watkins and farther west.

The lower part is composed of thin, somewhat uneven layers of dark dolomite and gray marly shales, and the upper of a bed of gypseous shale 35 to 45 feet thick in which thin limestones like those below occur.

This is the well known "land plaster" or gypsum bed that extends from Madison county to Genesee county, the rock which, when pulverized, was for many years considered valuable and extensively quarried as a fertilizer and one of the most important of the economic resources of the State. At present though fallen into disuse for that purpose, it is utilized as an important component in the production of prepared wall plaster. The formation received its name from the town of Camillus, Onondaga co., where the first discovery of gypsum in the United States was made in the year 1792.

A large number of gypsum quarries were formerly operated in the Camillus in the region on the east side of Cayuga lake north of Union Springs but nearly all of them have been long abandoned and afford only small exposures of the gypsum and overlying limestones. The large quarry of the Cayuga Land Plaster Company, formerly known as the Backus quarry, situated east of the railroad at Cayuga Junction shows very favorably nearly all of the gypsum bed and a few feet of the Bertie waterlime that succeeds it. There are several old pits on Hibiscus point, also near Crossroads, and 1½ miles farther north.

Outcrops of gypsum occur in the banks of both branches of Sawyers creek, and the cliff in the northern part of the village of Cayuga shows the upper part of the bed and the overlying limestone. An old gypsum pit, now nearly obliterated, situated between two drumlins 2 miles north of Cayuga and ½ mile east of the Mud Lock, seems to be the most northern point at which gypsum has been quarried on this quadrangle.

The only fossil known to occur in the Camillus shale, and that very rarely, is the ostracod Leperditia alta Conrad, though obscure traillike markings sometimes seen may owe their origin to another form of animal life.

Bertie waterlime

The gypsum beds are overlain by evenly bedded impure magnesian limestone, medium hard and dark colored when freshly broken, but weathering to a light bluish or yellowish gray on exposure and becoming softer.

Faint deposition lines may be discerned throughout the formation but the heavier layers which are 1 to 2 feet thick are usually quite compact, breaking with a conchoidal fracture, while a few of the others show quite distinct laminations and weather into a hard slaty shale. Toward the west it becomes somewhat thicker and is less homogeneous. In Erie county it is 49 feet thick and the upper part is the cement rock from which a large quantity of natural or waterlime cement is manufactured while the stratum next below is a dark slaty rock.

Waterlime cement was formerly made in the vicinity of Cayuga Junction and near Auburn from outcrops of this rock, but none is made now.

Fossils are rare in this formation as exposed on the Auburn quadrangle, a few Lingulas of two species, an Orbiculoidea, a Rhynchonella with Leperditia alta and fragments of eurypterids constituting the fauna here, but in Erie county the cement rock has afforded a large number of remarkably fine specimens of eurypterids and phyllocarids of the following species:

Ceratiocaris acuminata *Hall*
Eurypterus lacustris *Hall*
E. lacustris *var.* pachycheirus *Hall*
E. remipes *De Kay*
E. pustulosus *Hall*
E. dekayi *Hall*
Dolichopterus macrocheirus *Hall*
Eusarcus scorpionis *Grote & Pitt*
Pterygotus buffaloensis *Pohlman*
P. cobbi *Hall*

Also Leperditia scalaris Jones and a few Orbiculoideas and Lingulas and traces of the seaweed Bythotrephis lesquereuxi Grote and Pitt.

Bertie waterlime was exposed at the top of the wall in nearly all of the old gypsum quarries and small outcrops and loose blocks are still to be found at such localities. It is to be seen at the south end of the quarry at the plaster works; along the railroad at Cayuga Junction and at Crossroads; in several of the old pits near the four corners 1½ miles north of Crossroads and at the top of the wall of the old quarry at Cayuga.

Cobleskill limestone

Succeeding the Bertie waterlime there are three or four layers aggregating 8 to 10 feet of harder, darker limestone that has received the above designation from the favorable exposures of this rock in its most typical condition along Cobleskill creek, Schoharie county, where it has a thickness of 6 feet.

It thins out toward the west, from the Cayuga lake region to Phelps, Ontario co., but reappears farther west and attains its greatest thickness at Falkirk, Erie co., where it is known as the "bullhead" and is 14 feet thick.

On these quadrangles this limestone is seen to the best advantage on Frontenac island at Union Springs where the sharp elevation of the strata toward the north brings the three layers of the formation successively into view. The upper layer has a thickness of 3 feet 2 inches and breaks readily under the hammer into small angular fragments. This is the most fossiliferous layer except in Stromatopora. The middle layer is 2 feet 10 inches thick and contains Stromatopora concentrica Hall in great abundance, and except that it is a little darker colored, it has precisely the same appearance as the Stromatopora layer of the Manlius limestone which is 50 to 60 feet higher in the section.

The lower layer, 2 feet 6 inches thick, weathers to a lighter color than the two upper ones and is less fossiliferous, approaching the character of the upper layers of the Bertie waterlime below it. The thickness of these divisions is probably not maintained for any great distance but the character of the rock is quite uniform.

On the mainland the most southern exposure of this limestone is on the southeast side of Howland point where the upper layers are well displayed.

The old O'Conner quarry, 2 miles north of Union Springs, on the east side of the Cayuga road, shows 4 feet 8 inches of Cobleskill with 6 feet of Bertie below it and the exposure extends several rods north over the remarkable conical uplifts hereinafter further described. The cap layer of the old Wooley quarry on the east side of the road 1 mile south of Crossroads is Cobleskill limestone and it appears at the top of the railroad cut 40 rods east of the station at Crossroads.

At the old Thompson quarries near the four corners 1½ miles north of Crossroads there are several old gypsum pits in which there are small exposures of Bertie waterlime and the Cobleskill outcrops slightly at the roadside 60 yards north of the corners with Bertie below, and it is to be seen in place 125 yards farther west and there are many loose fragments of the more fossiliferous layer near by.

The largest exposure and the one most favorable for examination of the strata and collection of the fossils of this formation on these quadrangles is ⅝ mile southeast of Aurelius station on the New York Central Railroad where an outcropping ledge extends many rods north and south of the road to Aurelius, in which there is an old quarry and the upheaval of a row of rock cones, similar to those previously mentioned as occurring at the O'Conner quarry, has broken and disturbed the heavy layers in an unusual and very striking manner. Two small outliers or rocdrumlins of Cobleskill are located a mile farther north. The New York Central Railroad cuts through the north end of a drumlin 1½ miles northeast of Aurelius station, and another a mile farther east. The surface contour of the Cobleskill may conform to the shape of these hills but the rock does not appear on the surface.

At the foot of the hill next east of the crossing of the road leading north from the village of Aurelius and the New York Central Railroad, a small quarry on the south side of the railroad shows 4 feet 8 inches of Cobleskill at the base of the section and a few feet of Rondout waterlime above it. Manlius and Onondaga limestone outcrop 60 to 80 feet higher at the crest of the hill.

This formation is covered by drift in the region north of Auburn, except possibly a small outcrop by the side of the Lehigh Valley Railroad a mile south of Throop, but it is fairly exposed 8 rods northwest of the Sennett station of the New York Central Railroad and a ledge of the Cobleskill limestone crosses the little brook west of the station 10 rods south of the railroad.

Fossils. The following species have been identified from Frontenac island:

Chaetetes (Monotrypella) arbusculus *Hall*
Favosites niagarensis *Hall?*
Halysites catenulatus (*Linné*)
Stromatopora concentrica *Hall*
Cyathophyllum hydraulicum *Simpson*
Crinoid *sp.*
Chonetes jerseyensis *Weller*
C. undulatus *Hall*
Rhynchonella pisum *Hall & Whitfield*
Spirifer crispus *var.* corallinensis *Grabau*
S. vanuxemi *Hall*
Stropheodonta bipartita *Hall*
S. textilis *Hall*
S. varistriata (*Conrad*)
Whitfieldella sulcata (*Vanuxem*)
Ilionia sinuata *Hall*
Megambonia aviculoidea *Hall*
Pterinea subplana (*Hall*)
Bucania *sp.*
Cyclonema *sp.*
Loxonema *sp.*
Trochoceras gebhardi *Hall*
Tentaculites gyracanthus (*Eaton*)
Gomphoceras septore *Hall*
Orthoceras trusitum *Clarke & Ruedemann*
Orthoceras *large sp.*
Beyrichia *sp.*
Leperditia alta *Conrad?*
L. *cf.* scalaris *Jones*

Rondout waterlime

This formation is composed of dark colored waterlime closely resembling cement rock and shows faint lines of deposition and a tendency to split along these lines. It is 25 to 30 feet thick at Union Springs and increases 10 feet or more in the northeastern part of the quadrangle, and to 45 feet in Onondaga county, but decreases westward to 9 feet at Seneca Falls and is not recognized in the western part of the State.

It is 24 feet thick and the basal layers are extensively quarried for cement at Rondout, Ulster co., N. Y., whence the name of the formation is derived. The contact with the Cobleskill limestone is quite abrupt and is plainly seen where exposed, but at the top the transition to the Manlius limestone is a gradual one and in old exposures not readily discerned.

Rondout waterlime is exposed in the northern part of Union Springs in the gutters of the street leading eastward up the hill opposite the mill pond, and in the old quarry a few rods north of the O'Conner quarry 1¼ miles farther north. It appears at the top of the east end of the cut 50 rods east of the station at Crossroads, and there are several small exposures and numerous blocks of it in the region east of Aurelius station. It may be seen by the side of the New York Central Railroad and along Crane brook a mile west of Auburn. The contact with Cobleskill limestone is shown in the small old quarry at the foot of the hill on the south side of the railroad a mile farther west.

A shallow cut of the Lehigh Valley Railroad 2 miles north of Auburn shows Rondout waterlime and it is well exposed along and near the New York Central Railroad east of Sennett.

Fossils. The fauna of the Rondout waterlime in this region comprises but few species and they are very rare. Leperditia alta Conrad and L. scalaris Jones occur and fragments of eurypterids are occasionally found.

Manlius limestone

This formation, formerly well known as Tentaculite limestone, is 77 feet thick at Manlius, Onondaga co., but it diminishes rapidly toward the west and disappears in the vicinity of Seneca Falls.

It is composed of a series of distinct layers of hard, dark blue limestone from 2 to 5 feet thick, separated by thin partings of black bituminous matter. Some of these layers are quite compact and the lines of deposition are faint, but in others the rock has a straticulate appearance due to an alternation of thin plates of dark bituminous limestone and lighter colored impure limestone or waterlime. The laminations are from ¼ to 2 inches thick and exposure makes the contrast more noticeable.

The rock splits easily along the lines of deposition and breaks into angular blocks making it valuable for building purposes and road metal.

It is exposed to the thickness of 18 feet 8 inches in the extreme southern quarry on the east side of the Lehigh Valley Railroad a mile south of Union Springs, where it is separated into five distinct layers, with Onondaga limestone above, separated from it by a thin uneven band of dark material representing the Oriskany sandstone.

In the upper bed, 4 feet 5 inches thick, the rock is blue gray with faint lines of deposition and few fossils. The next bed in descending order is 5 feet 3 inches thick and contains Stromatopora concentrica Hall abundantly, making the limestone somewhat purer and harder than the adjacent layers.

This stratum possesses the same condition eastward across Cayuga and Onondaga counties and is well known as the upper Stromatopora layer, a stratum of almost precisely the same appearance in the Cobleskill limestone on this quadrangle and farther west being distinguished as the lower Stromatopora layer.

The stratum next below, 3 feet 1 inch thick, contains the fossil less abundantly and it is absent in the two lower tiers.

Manlius limestone is also exposed in the ravine in the rear of the sanatorium in the village of Union Springs and in the old quarry near the residence of Mr George Backus 1 mile north of the village from which a large amount has been utilized in building inclosure walls along the highway in the vicinity. The upper beds have been quarried on the Yawger farm 3 miles northeast of Union Springs where they are overlaid by 4 feet 6 inches of Oriskany sandstone, and the formation outcrops half a mile farther north on a hill on the east side of the highway leading to Crossroads. A quarry half a mile west of the Lehigh Valley Railroad station in the city of Auburn shows Manlius limestone at the bottom at the north end with Oriskany sandstone and Onondaga limestone above it. Nearly all of the large quarries in the face of the rock escarpment that extends across the northern part of the city are in the Manlius, with Oriskany at or near the top of the section. The old Phelps quarry on the east side of the highway 2 miles south of the village of Sennett displays the formation finely and several abandoned quarries near the northeast corner of the quadrangle afford most excellent opportunity for examination of the stratigraphy and the fauna of this the highest member of the Siluric system on the Auburn quadrangle.

Fossils are common throughout the formation and very abundant in some parts. The number of species is quite limited, however, the fauna in this locality, so far as observed, consisting of the following:

Chaetetes (Monotrypella) arbusculus *Hall*
Stromatopora concentrica *Conrad*
Schuchertella interstriata *Hall*
Spirifer vanuxemi *Hall*
Stropheodonta varistriata (*Conrad*)
Whitfieldella laevis (*Vanuxem*)
W. sulcata (*Vanuxem*)
Holopea antiqua *Vanuxem*
Tentaculites *sp.*
Leperditia alta *Conrad*

DEVONIC

Oriskany sandstone

The basal member of the Devonic system, interstratified between the Manlius limestone and the Onondaga limestone in the central and western parts of the State is an intermitting stratum or series of thin lentils, of coarse pinkish or white sandstone or quartzite, or where these are wanting, a thin mass of black bituminous mud with pebbles of black sand or waterlime. At some outcrops these pebbles occur embedded in the lower part of the heavy layer of limestone that succeeds this horizon.

The line of outcrops of this horizon shows cross sections of the sandstone lentils west of this locality to be quite thin, one exposed in the village of Phelps that measures 6 feet 6 inches being the thickest, and one penetrated by the Livonia salt shaft 4 feet 9 inches thick. The thickness increases eastward attaining 25 feet in a lentil in the western part of Onondaga county and the formation is well developed in the vicinity of Oriskany Falls, whence the name, first applied by Vanuxem in his report on the Geological Survey of the Third District for 1839.

In the Oriskany horizon in the old Shaliboo quarry 1 mile south of Union Springs there are 10 inches of dark conglomerate composed of bituminous shale in which there are embedded many pebbles and fragments of waterlime. A stratum of calcareous sandstone 1 foot 6 inches thick, exposed on the north side of the bridge on Center street in Union Springs in which there are many pebbles, represents this formation. An outcrop of typical Oriskany sandstone 2 feet 3 inches thick and containing many fossils occurs on a knoll a few rods south of the residence of Mr George D. Backus. An old quarry in the woods 50 rods west of the Yawger cemetery 1½ miles northeast of Union Springs shows 9 feet of friable pinkish sandstone in three layers, all fossiliferous, the lower one 4 feet thick being fairly crowded with large brachiopods.

In the woods on the Yawger farm ¾ mile north of the cemetery, a ledge extending in a north and south direction 35 to 40 rods, shows Oriskany sandstone 5 feet 6 inches thick in the central part and extraordinarily fossiliferous. Vanuxem refers to this locality on page 127 of the report on the Third District, 1842, and says of it: "The fossils are numerous, and better preserved than in any other locality of the district, state or country that has come to our knowledge, the rock being more solid and the sand of which it is composed purer and whiter."

Where exposed in the western part of the ledge at the crest of the hill 1¾ miles north of Aurelius it is 2 feet 1 inch thick in ordinary condition and has many fossils in the lower part of the stratum. It is 10 to 12 inches thick in the old quarries in the northern part of Auburn west of the crossing of North street and the New York Central Railroad, and a small outcrop near the northeast corner of the quadrangle shows about the same thickness.

The occurrence of the fossils of large size and in some outcrops, as north of Union Springs, in great abundance, tends to produce the impression that the fauna of the sandstone in this region is a large one,

but the number of species is quite limited. The more prominent and persistent forms occurring in this rock in the central part of New York are:

Spirifer arenosus (*Conrad*)
S. murchisoni *Castelnau*
Rensselaeria ovoides (*Eaton*)
Hipparionyx proximus *Vanuxem*
Chonostrophia complanata *Hall*
Meristella lata *Hall*

Onondaga limestone

The heavy beds of bluish gray limestone with embedded nodules and nodular layers of chert or hornstone overlying the Oriskany sandstone and succeeded by the black Marcellus shales, was designated "Cornitiferous limestone" by Prof. Amos Eaton in 1839, and in the early reports of the Geological Survey was considered in two divisions. The basal member, which is usually free from chert and but a few feet thick is the "grey sparry limestone" of the annual reports. In his report on the Fourth Geological District (1839) James Hall first used the term Onondaga limestone, applying it to this basal division of the formation. The overlying cherty beds composed the "Seneca limestone" of the early reports and the "Corniferous limestone" of the final reports of Hall and Vanuxem in 1842.

The name "Onondaga Salt Group," applied to the Vernon and Camillus shales, was used in the annual and final reports of the Geological Survey but discontinued some years after. In Clarke and Schuchert's revised "Classification of the New York Geologic Formations" the term Onondaga limestone is expanded to include all of the strata between the Oriskany horizon and the Marcellus black shales.[1]

The limestone is usually separated by thin partings of shale or bituminous mud into even compact layers or tiers from 6 inches to 3 feet thick, some of which are nearly or quite free from chert and are valuable as building stone, while others contain a considerable proportion of the flint or hornstone and are utilized extensively when crushed as road material. Shaly tiers occur at some localities but the beds are mostly compact. The hundreds of quarries in the Onondaga limestone along its line of outcrops from the Hudson valley to the Niagara river attest its importance among the economic resources of the State and show the enormous amount of this rock that has been and is still being utilized.

[1] For a more detailed history of the names applied to this formation see State Museum Bulletin 128.

On the Auburn quadrangle quarry walls and field outcrops make an almost continuous series of exposures of the Onondaga extending from the extreme western point of Long point on Cayuga lake to the northeast corner of the quadrangle. Fifteen feet of the lower beds and the Oriskany contact are well shown in the old Shaliboo quarry a mile south of Union Springs. The next quarry at the north between the railroad and the highway exposes 40 to 50 feet of the middle and upper tiers and the old Wood quarry on the hill east of the highway affords a long exposure of the upper beds, with the contact line and 15 feet of Marcellus black shale and impure limestone at the top of the quarry wall.

Owing to the northward dip of the strata at this point the newer quarry at the north on the east side of the road, though about 25 feet lower, shows the same section and it is also shown in a large quarry on the hill a mile east of Union Springs.

The drift sheet is thin over all the region between Union Springs and Auburn where the Onondaga limestone is the surface rock and outcrops are frequent. The lower beds are exposed just north of Oakwood and the top layers in the hill ⅜ mile south of Half Acre. In the vicinity of Aurelius there are broad areas where the limestone is but partially covered and a ledge 50 rods long at the crest of the hill on the south side of the railroad 2 miles north of Aurelius exposes the Oriskany contact and 15 to 25 feet of the lower beds.

It lies near the surface and is exposed in numerous places in the northern parts of Auburn and thence northeastward in many quarries and field outcrops in the vicinity of the New York Central Railroad to the east line of the quadrangle.

Fossils are exceedingly abundant in nearly all parts of the limestone layers and occur frequently in the chert and the shaly partings. A list of the species contained in this formation published in State Museum Bulletin 63 for the Canandaigua-Naples quadrangles includes 3 fishes, 39 crustaceans, 13 cephalopods, 3 pteropods, 38 gastropods, 15 lamellibranchs, 48 brachiopods, 4 crinoids and 30 corals, a total of 193 species.

Marcellus black shale

On page 146 of the report on the Geological Survey of the Third District, 1842, Vanuxem describes the Marcellus shales under two divisions: the "lower, calcareous, fossiliferous, and somewhat fissile; the upper, shaly, breaking into small irregular fragments" and further says: "These shales extend east and west through the district commencing near the Hudson and ending on Lake Erie. They are con-

veniently divided into two masses, from the presence of limestone and fossils in the one and their absence in the other."

On page 177 of the report on the Fourth District, Hall describes the lower division and adds: " This division terminates upward by a thin band of limestone above which the shale is more fissile and gradually passes from black to an olive or dark slate color."

The limestone here referred to is now known as the Stafford limestone. It is 8 to 10 feet thick in Erie county and diminishes gradually to 4 inches on Flint creek in Ontario county. This hard limestone layer is not found in exposures of this horizon east of Flint creek but a band of gray calcareous shale containing many species belonging to the fauna of the Stafford limestone, and that are absent from or very rare in the adjacent shale, serves to mark the point of separation between the two divisions of these dark shales.

The term Marcellus black shale as now used applies only to the lower division, succeeding the Onondaga limestone and overlaid by the Stafford limestone or in its absence, the lighter shales of the second division now known as the Cardiff shales. Its thickness is 45 to 50 feet on the Auburn quadrangle.

The change is abrupt from the blue Onondaga limestone to the black Marcellus shales in Madison and Onondaga counties but a few thin calcareous layers are interstratified in the succeeding 13 feet and a hard stratum 2 to 3 feet thick, known to geologists as the Agoniatite limestone occurring at this horizon, is a persistent and easily recognized feature of the Marcellus section from Schoharie county to the town of Phelps, Ontario co., where it is finely exposed in the bed of Flint creek.

The shales that intervene between the Onondaga and the Agoniatite layer in eastern central New York become more calcareous toward the west and on this quadrangle this bed is composed principally of impure limestones in layers a few inches thick with partings of black shale, and a 5 inch stratum of shale at the base. At the exposure in the bed of Flint creek the proportion of calcareous matter is still larger and in the western part of the State the Agoniatite layer and the strata below it have become so far assimilated to the Onondaga limestone as not to be readily distinguished from it.

The remaining upper part of this formation is a bed of black shale the only notable feature of which is a row of spherical concretions 2 to 3 feet in diameter found in this horizon wherever exposed in the central and western part of the State.

Exposures. The black upper shales with large concretions are exposed by the lake shore on the east side of the Lehigh Valley Railroad 1¼ miles north of Levanna. The Agoniatite limestone with 15 feet of black shale above it and the impure limestone layers below, down to the Onondaga limestone, are finely displayed in the upper part of the old Wood quarry a mile south of Union Springs and the lower impure limestones in Wood's new quarry and the Smith quarry 1 mile east of Union Springs also.

The Agoniatite layer outcrops slightly by the roadside a mile east of Half Acre and the black upper beds are displayed in the new railroad cut half a mile farther east.

Marcellus shale crops out slightly in the bed of the stream ¼ mile north of Soule's cemetery on the Auburn Road (N. Y. C. & H. R. R. R.) 3½ miles east of Auburn and 2 miles northeast of the city in the bank of a small ravine that crosses the road leading from Grant avenue to Franklin street. The large concretions are seen here. The Agoniatite limestone and adjacent black shales outcrop ¼ mile from the east line of the quadrangle by the side of the third east and west road from the north line of the quadrangle.

Fossils. The lower shales contain:

Orthoceras subulatum *Hall*
Styliolina fissurella (*Hall*)
Pleurotomaria rugulata *Hall*
Liorhynchus limitare (*Vanuxem*)
L. laura *Billings*
Strophalosia truncata *Hall*
Ambocoelia umbonata (*Conrad*)
Chonetes mucronatus *Hall*
C. lepidus *Hall*
Orbiculoidea media *Hall*
Pterochaenia fragile (*Hall*)
Liopteria laevis (*Hall*)
Nuculites oblongatus *Conrad*
Panenka ventricosa *Hall*

A list of 28 species found in the Agoniatite limestone in Onondaga and Schoharie counties may be found in State Museum Bulletin 49, but the stratum appears to be less fossiliferous here. Fragments of the large cephalopod Agoniatites expansus (Vanuxem) occur in this layer at Wood's old quarry, Union Springs.

Cardiff shale

The Stafford limestone being absent from these quadrangles the Marcellus shale is succeeded by about 50 feet of dark shale until recently known as the upper Marcellus shale. In State Museum Bulletin 63, published in 1904, this formation was designated by

the above name on account of its abundant exposure in the vicinity of the village of Cardiff in Onondaga county.

It is composed of soft shales varying in character from medium light colored and calcareous to very dark and bituminous. It contains a row of medium sized spherical concretions and toward the top, thin calcareous lentils composed mainly of Liorhynchus limitare.

At the base a bed of rather light colored shale in the horizon ot the Stafford limestone is quite calcareous and contains many fossils most of which are common in the limestone in the western part of the State.

The upper beds are darker, and in some parts quite black and bituminous, and less fossiliferous. Near the top a band of very hard, dark calcareous shale or impure limestone that is continuous across this quadrangle and to Seneca lake, produces cascades in Great gully and Criss creek south of Union Springs. The succeeding shales above this stratum gradually become lighter colored and more argillaceous and pass into the next formation in the series, the Skaneateles shale.

Exposures. The Cardiff shale and the hard layer are exposed along the lake shore half a mile north of Levanna, the hard layer rising from the lake level in a bluff that reaches the hight of 12 feet, then with an eight per cent northward dip sinks below the lake to emerge again 15 rods farther north and rise rapidly in the 25 foot bluff that exposes also the dark shales with fossils immediately below it. The hard stratum produces a cascade at the bridge over the next stream south of Great Gully brook (Criss creek), with dark fossiliferous shales below it, and the gray fossiliferous band at the base of the formation is exposed in the bank of this creek north of the crossing of the private road ¼ mile farther north. In Great gully the hard layer appears at the crest of a cascade 6 feet high at the mouth of the ravine, 25 rods west from the lake road and, rising toward the east more rapidly than the bed of the stream, is at the crest of a second fall 5 feet high, and 50 rods up the ravine at the top of a third fall 17 feet high.

This stratum, with adjacent shales, outcrops by the roadside near the four corners on the hill 1½ miles south of Oakwood and also along the new railroad from Auburn southward through Genoa, 1½ miles south of Auburn.

Fossils. A full list of the fossils of the Stafford limestone and the Cardiff shale may be found in State Museum Bulletin 63.

The collector may expect to find the following species in the Cardiff beds south of Union Springs:

Phacops rana *Green*
Cryphaeus boothi *Green*
Homalonotus dekayi *Green*
Orthoceras subulatum *Hall*
Tornoceras discoideum (*Conrad*)
Tentaculites gracilistriatus *Hall*
Styliolina fissurella (*Hall*)
Pleurotomaria rugulata *Hall*
P. itys *Hall*
P. capillaria *Conrad*
P. sulcomarginata *Conrad*
Camarotoechia sappho *Hall*
Spirifer audaculus *Conrad*
Strophalosia truncata *Hall*
Productella spinulicosta *Hall*
Chonetes mucronatus *Hall*
C. scitulus *Hall*
Liorhynchus limitare (*Vanuxem*)
Ambocoelia umbonata (*Conrad*)
Orbiculoidea minuta *Hall*

Skaneateles shale

This name was applied to the beds next above the Cardiff as they appear near the foot of Skaneateles lake, by Vanuxem in his annual report for 1839; and in his final report on the Third District, 1842, it is mentioned as the first or lowest member of the Hamilton group.

It is a mass of dark soft clayey shale with some beds of black shale interbedded but gradually assuming on the whole a lighter color toward the top and contains some thin calcareous lenses composed of fossils and occasional concretions. The lines of contact with the adjacent formations are not clearly defined but on this quadrangle the Skaneateles beds have an estimated thickness of 200 feet. They are well exposed along the railroad between Aurora and Levanna and in the ravines of Glen creek, Criss creek and in Great Gully brook, also slightly just east of Fleming.

Fossils are not so abundant in the Skaneateles shale as in the succeeding Ludlowville beds. The following is a partial list of the species that may be found in this formation on these quadrangles:

Ambocoelia umbonata (*Conrad*)
Tropidoleptus coronatus (*Conrad*)
Athyris spiriferoides (*Eaton*)
Leptostrophia perplana (*Conrad*)
Orbiculoidea media *Hall*
Chonetes coronatus *Hall*
C. mucronatus *Hall*
Spirifer audaculus *Conrad*
Productella spinulicosta *Hall*
Grammysia arcuata *Conrad*
Pterochaenia fragilis (*Hall*)
Actinopteria boydi *Hall*
Modiomorpha subalata (*Conrad*)
Buchiola retrostriata (*von Buch*)
Nuculites corbuliformis *Hall*
Styliolina fissurella (*Hall*)
Tornoceras discoideum (*Conrad*)
Orthoceras subulatum *Hall*
Cryphaeus boothi *Green*
Phacops rana *Green*

Ludlowville shale

Next above the Skaneateles beds there are about 25 feet of lighter colored, sandy shales somewhat calcareous and harder than the beds below and above. This band is abundantly fossiliferous containing many large brachiopods and cyathophylloid corals. It is continuous across this quadrangle and westward, with an increasing proportion of calcareous matter and fossils to Ontario county, appearing at Centerfield, 5 miles west of Canandaigua as a distinct stratum of limestone largely composed of corals.

It is succeeded here by about 100 feet of soft dark shales similar in character to the Skaneateles and containing a somewhat similar fauna.

The upper beds gradually become more sandy, lighter colored and fossiliferous. Thin calcareous lenses, masses of crinoid stems and other fossils occur and there are many small concretions.

The formation is terminated at the top by a continuous layer of crinoidal limestone, formerly the "encrinal limestone," now known as the Tichenor limestone.

These beds were first designated Ludlowville shales by Professor Hall in his report on the geology of the Fourth District (for 1838) 1839.

Exposures. The upper and more fossiliferous part of this formation is exposed along the east side of the Lehigh Valley Railroad for nearly a mile in the vicinity of Portland (or Shurger) point, and also to the thickness of 25 feet in the north bank of Salmon creek a mile below Ludlowville. It is below the lake level from the north side of Myers point to Atwaters, but is abundantly displayed in the cliff and ravines along the lake shore and railroad, almost the entire distance between Atwaters and Stony point, the upper beds being most conveniently exposed in the vicinity of King Ferry, and the lower fossiliferous band at Willetts and Stony point.

The soft shales of the middle portion of the formation appear in walls of the ravine of Payne's creek and the upper beds capped by the Tichenor limestone at the falls.

There are many outcrops of Ludlowville shale in the small ravines north of Aurora and on the crest of the ridge 2 to 4 miles south of Fleming. The lower beds are finely exposed along the road ½ mile southwest from Wykoff and the ravine at Ensenore displays almost the entire Ludlowville section and there are fine exposures along the railroad north and south of Ensenore.

The fauna of the Ludlowville shale is a very large one. For list of species see State Museum Bulletin 63 under Canandaigua shale and Bulletin 99.

Tichenor limestone

A stratum of hard bluish gray limestone 10 to 14 inches thick overlies the Ludlowville shale at all exposures of this horizon from Onondaga county to Lake Erie, showing little variation in character though its fossils are much more abundant and better preserved at some exposures than at others.

It usually is composed largely of crinoid stems, and for this reason received the designation Encrinal limestone from Hall in his annual report on the geology of the Fourth District (for 1838) 1839 and by which it was known until the term Tichenor limestone was applied to it by Clarke in State Museum Handbook 19, from its favorable exposure in Tichenor gully on the west shore of Canandaigua lake. In the southern part of the Genoa quadrangle, in addition to the hard layer, there are 2 to 3 feet of hard calcareous shale and thin limestones that clearly belong to this division.

The most southern exposure of the Tichenor limestone in the Cayuga lake valley is on the east side of the Lehigh Valley Railroad 25 rods south of the cement factory at Portland or Shurger point. It is here a calcareous band 2 feet 9 inches thick, the upper part 18 inches thick being quite hard and compact and the remainder, except a few thin layers, quite shaly.

There are two thin limestones of similar character 5 and 7 feet higher, and the Ludlowville shales below are highly calcareous and fossiliferous. In Shurgers glen the hard layer is exposed at the top of the falls 50 feet above the lake level and in some places contains masses of crinoid stems 8 to 10 inches thick.

It appears 45 feet above the lake level in a small ravine ⅜ mile north of Portland and in the north bank of Salmon creek at Myers 20 feet higher than the lake.

It is above lake level for a few rods at the mouth of Willow creek on the west side of the lake, but is submerged from that point to Kidders where it emerges and rising rapidly toward the north and west produces the lower falls in the ravines of Sheldrake, Groves and Barnum creeks.

On the east side it emerges at Atwaters and is well exposed along the railroad and in several ravines between Atwaters and King Ferry. In the ravine at the latter place it forms the crest of the second falls, 30 feet above the lake, and is also at the top of high falls in three ravines near the lake north of King Ferry.

It forms the crest of the falls in the ravine of Paynes creek and rising toward the southeast, appears in the bed of the stream several times between the falls and the forks of the creek.

No outcrops of the Tichenor are known on the gently sloping higher part of the ridge between the lakes, but it is finely exposed at the top of a fall in the Ensenore ravine 20 rods below the first highway bridge over the stream west of the station. It is very rich in fossils here, specially large trilobites and brachiopods, and there are several characteristic masses of crinoid columns.

It appears similarly situated and in the same condition in several ravines south of Ensenore.

The fossils found in the Tichenor limestone are members of the Hamilton fauna and of the same species as occur in the Ludlowville and Moscow shales. For list see State Museum Bulletins 69 and 99.

Moscow shale

The stratigraphic position of this formation is well defined on this quadrangle by the Tichenor limestone at the base and the Tully limestone at the top, both of which show a marked contrast to the medium dark gray soft shales of which it is composed, the few thin calcareous lentils interstratified with the shales not being of sufficient importance to cause any difficulty of identification. It has a thickness of 130 feet.

The light colored middle and lower parts contain fossils in great abundance, but in the darker upper beds they are comparatively rare. For details of the fauna of the Moscow shale see State Museum Bulletin 63.

On the west side of Cayuga lake the large ravines of Bloomer, Grove and Sheldrake creeks cut through the Moscow shale and the numerous small ravines south of Kidders and the shore cliffs as far as Little point show the upper beds to good advantage, and the entire section is displayed between Taghanic point and a mile from the south line of the quadrangle.

On the east side of the lake, exposures of Moscow shale begin half a mile from the south line of the quadrangle and, except for 1¼ miles south of Lansing where it is below the lake level, appear in all of the ravines and shore cliffs for 12 miles toward the north to near King Ferry (Clearview) and in the upper part of several ravines farther north, also in the Paynes creek ravine and the one below Chapel Corners.

The more accessible and favorable exposures of the entire section are: along the railroad south of Portland point; in Shurgers glen and the Salmon creek ravine; the ravines near Atwaters and King Ferry also show the whole section.

There are but few outcrops of the Moscow shale in the Owasco lake valley within the limits of the Genoa quadrangle but a few miles farther south in the ravines near Moravia the formation is well exposed.

Tully limestone

From near the west shore of Canandaigua lake in the town of Gorham, Ontario co., to Smyrna, Chenango co., a hundred miles east, the Moscow shales are overlain by the Tully limestone, so named by Vanuxem in his report on the geology of the Third District for 1838.

On these quadrangles the formation is composed of four to six compact layers of fine grained blue black limestone that weathers to a light gray or ashen color and has an aggregate thickness varying between 14 and 21 feet. The rock is very hard when fresh but after long exposure breaks easily into small angular fragments. The basal layer which is very hard is 7 to 9 feet thick at some exposures, the others varying from 1 to 4 feet. Frequent joints divide the strata into large blocks that become detached and are strewn along the lake shores at the base of cliffs in which the limestone occurs and in the bottom of many ravines below cascades produced by it.

The passage from the soft Moscow shale to the base of the limestone is very abrupt but at the top the overlying Genesee shale is quite calcareous for a few feet.

At the top of the low fall where Taghanic creek flows over the limestone at Taghanic point the normal Tully is overlain by 2 feet 4 inches of dark impure limestone succeeded by about the same thickness of densely black Genesee shale that is succeeded by a 12 inch stratum of dark limestone exposed in the sides and bottom of the stream for about half a mile. As the few fossils in these calcareous layers are of species common in the Genesee shales they are assigned to that formation.

Exposures. The Tully limestone is exposed for several miles in the cliffs along the shores of Cayuga lake and in a large number of ravines cut in the hills it forms the crests of falls or cascades and appears in the rock walls, the hard light colored limestone projecting from the dark soft shales and producing the most striking and picturesque effects.

It emerges, forming a low cliff, on the west side of the lake ¾ mile from the south line of the quadrangle, rises rapidly to 144 feet above lake level in Willow creek, then descends to lake level half a mile north of Taghanic point. It is submerged for 3½ miles, then appears in a cliff to Little point and in all the ravines to Barnum creek where

it is seen at the top of falls near the west line of the quadrangle 300 feet higher than the lake.

On the east side the top of the Tully is at lake level at a small point ½ mile from the south line of the Genoa quadrangle, but is covered by beach sand and gravel for 35 rods, then appears between the lake and the railroad, the lower layers submerged at the south end of the exposure but above the water 25 rods farther north. It is displayed in the cliff on the east side of the railroad for ⅛ mile and rises to 640 A. T. in the field ¼ mile north of Shurgers glen, in the vicinity of which it is well exposed in the quarry of the Portland Cement Company and adjacent fields and ravines.

It is at the top of the falls of Salmon creek at Ludlowville and appears at the top of the cliffs on the lake shore ½ mile north of Myers point, and almost continuously for 3 miles, sinking with a northward dip to partial submergence in the lake, then slowly rising, may be seen in the shore cliffs and at the top of falls in several ravines near the lake in an almost continuous exposure for 10 miles to King Ferry (Clearview).

The falls in some of the larger ravines are made exceedingly interesting and picturesque by the disintegration of the soft Moscow shales beneath the limestone which projects so far as to produce recesses or caves of considerable extent. One near the railroad a mile south of Lansing is 50 feet wide and 27 feet deep and there are others not much less extensive. Immense blocks of the limestone partly fill the ravines below the falls producing different but equally striking and rugged effects. The limestone rises rapidly and recedes from the lake shore north of King Ferry outcropping at 800 A. T. on the Aurora road and at the top of falls in two branches of Paynes creek.

It is well exposed at 830 to 850 feet in the ravine at Chapel Corners. This is the extreme northern outcrop of the limestone in the Cayuga lake valley and from this point to an outcrop in the highway near the four corners a mile north of Scipio its precise position is not known. It produces a cascade at 1160 A. T. in the Ensenore brook 1¼ miles farther south.

The limestone is 14 to 15 feet thick in the Barnum and Groves creek ravines, 17 feet 6 inches on Willow creek; 21 feet in Shurgers glen; 18 feet in the Portland Cement Company's quarry and 15 feet at Lake Ridge.

The Tully is usually found to be only moderately fossiliferous but there have been collected from the exposures in the Cayuga lake valley 70 species, of which 14 are corals, 26 brachiopods, 5 lamellibranchs, 15

gastropods, 8 cephalopods and 2 trilobites, besides crinoid stems and unidentified corals.

For list of species see Sixth Annual Report of the State Geologist, 1887.

Genesee black shale

This term was formerly used to designate all of the thick mass of black and dark shale that succeeds the Tully limestone, up to the base of the light colored Cashaqua shale, but for reasons fully set forth in State Museum Bulletin 118, it is now applied only to the more densely black and bituminous lower beds that lie between the Tully limestone and a thin but well defined, calcareous band known as the Genundewa limestone that from Ontario county westward to Lake Erie separates the beds formerly called the lower Genesee shales from the somewhat lighter colored and more calcareous upper Genesee shales.

The limestone is absent in the Cayuga lake valley but the upper limit of the Genesee shale is well marked by an abrupt change to a light gray calcareous shale in the place of the limestone. Two hard layers 1 foot 6 inches and 12 inches thick near the base of the Genesee in the southern part of the Genoa quadrangle are impure limestone but as the few fossils they contain are of the species found in the higher beds, they are, as previously stated, classified as Genesee. There are also a few calcareous concretions but otherwise this formation is quite uniform in character from bottom to top. Though fissile after exposure the rock when fresh is compact and quite hard, and is less susceptible to erosion than more clayey shales. The beds are usually traversed in two or more directions by vertical joints that divide the surface in small square, triangular or diamond shaped tesselations 1 to 3 or 4 feet across.

Fossils are not abundant in the Genesee shale but the collector may expect to find:

Liorhynchus quadricostatum *Hall*
Chonetes lepidus *Hall*
Lingula spatulata *Hall*
Orbiculoidea lodensis (*Vanuxem*)
Pterochaenia fragilis (*Hall*)
Pleurotomaria rugulata *Hall*
Styliolina fissurella (*Hall*)
Tentaculites gracilistriatus *Hall*
Probeloceras lutheri *Clarke*
Bactrites aciculum (*Hall*)

The Genesee shales are exposed in the cliffs on the east side of the lake near the south line of the quadrangle and at most of the exposures of Tully limestone previously mentioned. This formation attains its greatest thickness in this State, about 100 feet, in Ontario

and Yates counties. It diminishes westward to 1 foot on the shore of Lake Erie and eastward to 65 feet on the Genoa quadrangle and is not known east of Smyrna, Chenango co.

Genundewa limestone

This formation which is fully described in State Museum Bulletins 63 and 118, is a band of thin limestones and calcareous shale extending from Gorham, Ontario co. to Lake Erie. The limestones are composed in a large proportion of the shells of the minute pteropod Styliolina fissurella (Hall) and was formerly known as the Styliola limestone. Except in a few small patches the limestone does not appear in characteristic condition in the Seneca lake valley, but its position is clearly indicated by a band of light gray calcareous shale containing a row of large concretions. Fossils common to the limestone farther west, particularly Styliolina fissurella, are abundant in both shales and concretions, [*see* State Mus. Bul. 128]. The formation is less clearly defined in the Cayuga lake valley but may be seen in the rock wall at the Trumansburg creek falls at Frontenac point and at Taghanic Falls.

On the east side of the lake it appears as a rather faint gray band in the cliffs near the south line of the quadrangle about 30 feet below the heavy sandstone that here marks the base of the Cashaqua shales.

The shale is darker, the concretions smaller and fossils more rare here but in the southern part of the Salmon creek valley it is more calcareous and fossils are more common.

It is exposed at the top of the falls in the ravine 2½ miles northeast of Ludlowville and in a 10 foot cliff on the west side of Salmon creek 20 rods north of the highway, 1 mile south of the forks of the creek. At this exposure the bed of the stream is black shale in which Orbiculoidea lodensis, Liorhynchus quadricostatum, Chonetes lepidus and other Genesee fossils are common, and the gray band about 10 feet thick with a row of concretions 1 to 2 feet in diameter and 5 to 8 feet apart at the base, succeeded by 1 foot 8 inches of soft gray shale and a harder stratum of calcareous shale 8 inches thick that is followed by 6 feet of gray shale. This horizon is exposed in 3 ravines on the east side of Salmon creek valley between Genoa and Venice Center, but the formation is not so clearly defined, the overlying shales, which are dark to black in the Seneca lake valley, differing but little here in appearance from these beds.

The following fossils have been found in this gray band in exposures in the Seneca lake and Cayuga lake valleys:

Manticoceras pattersoni (*Hall*)
Gomphoceras *cf.* manes *Hall*
Bactrites *sp.*
Paleotrochus praecursor *Clarke*
Pleurotomaria capillaria *Hall*
Loxonema noe *Clarke*
Styliolina fissurella (*Hall*)
Buchiola retrostriata (*von Buch*)
Palaeoneilo muta *Hall*
Pterochaenia fragilis (*Hall*)
Atrypa reticularis (*Linné*)
Ambocoelia unbonata (*Conrad*)
Chonetes scitulus *Hall*
Liorhynchus multicostatum (*Hall*)
Orbiculoidea lodensis *Vanuxem*
Lingula spatulata *Vanuxem*
Cladochonus, abundant in concretions
Crinoid stems

West River dark shale

In Ontario county and westward to Lake Erie the dark shales between the Genundewa limestone and the base of the Cashaqua shales are separable into two divisions: the West River shale, a heavy bed of soft dark colored slightly calcareous shales, and succeeding them, the blacker and more bituminous Middlesex shale.

In the Seneca lake valley the distinction between the two formations is scarcely recognizable and in the Cayuga lake valley it seems to be lost entirely and both formations by gradual change in the character of the sedimentation become so far assimilated to the succeeding Cashaqua shale that they are not to be distinguished from that formation east of this, or at farthest, the Moravia quadrangle. The horizon of the West River and Middlesex shales is exposed in the upper part of the Sheldrake and other ravines in that vicinity, also in the Trumansburg and Taghanic ravines and others in the vicinity of Heddens and King Ferry. In the Salmon creek valley these beds may be seen at the top of the falls in the ravine 2¼ miles north of Ludlowville, and in several gullies on the east side between Genoa and Venice Center.

Fossils are very rare in these beds but a few forms like those in the Genesee beds occur. Among these are:

Bactrites aciculum (*Hall*)
Gephyroceras *sp.*
Pterochaenia fragilis (*Hall*)
Lunulicardium curtum *Hall*
Buchiola retrostriata (*von Buch*)
Panenka *sp.*
Lingula spatulata *Vanuxem*
Orbiculoidea lodensis *Vanuxem*
Liorhynchus quadricostatum *Hall*

Cashaqua shale

This formation was named from its favorable exposure along Cashaqua creek, one of the tributaries of the Genesee river in Livingston county. In that locality it is composed almost entirely of light blue gray or olive shale, but toward the east it acquires a slowly increasing proportion of arenaceous matter and on this quadrangle there are frequent flags and thin sandstones, specially in the upper beds where some of the latter are 1 to 3 feet thick and usually schistose to a degree that makes them valuable for flagging, for which purpose they have been extensively quarried on both sides of the Cayuga lake valley.

Except that the shales in the lower part of the formation are rather less calcareous here than they are in the Genesee valley they are of much the same appearance and character.

The upper limit is at the top of a band of soft dark shale about 265 feet above the base and approximately, at least, in the horizon of the Rhinestreet shale that contains a few small lamellibranchs like those below and is succeeded by more arenaceous sediments that carry an abundant brachiopodous fauna.

The Cashaqua beds are exposed in the ravines between Heddens and Clearview and similarly on the opposite side of the lake, also farther north in the Trumansburg and Taghanic creek ravines. The upper flaggy beds are displayed in a number of large quarries now mostly abandoned between Taghanic Falls and Ovid Center, also at Goodyears and King Ferry. The lower beds appear in the ravines on the east side of the Salmon creek valley north of Genoa and along the west branch of Salmon creek in the vicinity of Little Hollow.

Fossils. The lower soft shales contain, though not abundantly, some members of the characteristic fauna of the Cashaqua beds farther west, viz:

Pterochaenia fragilis (*Hall*)
Buchiola retrostriata (*von Buch*)
Probeloceras lutheri *Clarke*
Bactrites aciculum (*Hall*)

Spirifer laevis *Hall* occurs at Taghanic Falls near the top of the lower beds

A thin layer of soft sandstone 35 feet higher exposed in Hunt's quarry 1½ miles southeast of Interlaken contains:

Spirifer mesacostalis *Hall*
Productella spinulicosta *Hall*
Camarotoechia congregata (*Conrad*)
Chonetes lepidus *Hall*
Palaeoneilo constricta (*Conrad*)
Leptodesma *sp.*
Conularia *cf.* continens *Hall*
Helianthaster gyalum *Clarke*
Stictopora
Melocrinus *sp.*
Plumalina

Burls in the higher sandstones contain:

Manticoceras pattersoni (*Hall*)	Orbiculoidea *sp.*
Orthoceras bebryx *Hall*	Leptostrophia mucronata (*Conrad*)
Liorhynchus mesacostale *Hall*	Grammysia subarcuata *Hall*
Cyrtina hamiltonensis *Hall*	Cladochonus *sp.*

and masses of plant remains in which fragments of Lepidodendron are frequent. A considerable number of additional species have been collected from this formation on the Ithaca quadrangle where it is favorably exposed about the head of Cayuga lake.

From Lake Erie eastward as far as Seneca lake the Cashaqua shale succeeds the black Middlesex shale and is overlaid by another band of black shale known as the Rhinestreet black shale, a formation that reverses the usual order and decreases in thickness toward the east and is not recognized with certainty in the Cayuga lake valley. Both these formations are absent in the Genoa district. Near the south line of the Genoa quadrangle the basal layer of the Cashaqua is a compact sandstone nearly 3 feet thick that thins out toward the north and disappears in a few miles but the contact is still plainly marked by the abrupt change in the color of the rocks.

Hatch shales and flags

This formation as exposed on the slopes of Hatch hill in the Canandaigua lake section is clearly defined by the Rhinestreet black shale upon which it rests and the Grimes sandstones by which it is overlain. It there, as here, consists of shales and thin sandstones in frequent alternations, but is thinner and less arenaceous, and though it contains a few fossils, they all belong to the Naples fauna from which brachiopods are, with the exception of a small Lingula, entirely absent.

In the Seneca lake section these beds are found to contain a few brachiopods and the lamellibranchs and cephalopods of the Naples fauna are less common. In the Cayuga lake valley, and specially in the southern part, the number of species of brachiopods and lamellibranchs that are not known in the horizon of these beds in the Naples or Genesee river section is greatly increased, while the representatives of the Naples fauna have almost, though not quite, disappeared.

The thickness of this formation on the Genoa quadrangle is 350 to 375 feet, lack of favorable exposures making precise measurement impracticable. The numerous exposures of this formation about Ithaca 6 to 10 miles south of the Genoa quadrangle have afforded about 50 species of fossils constituting the well known Ithaca fauna.

On the Genoa quadrangle exposures are less favorable, and the beds apparently less fossiliferous.

The collector may expect to find:

Stictopora meeki *Nicholson*
Aulopora *sp.*
Spirifer mesacostalis *Hall*
S. mesastrialis *Hall*
Cyrtina hamiltonensis *Hall*
Leptostrophia perplana *var.* nervosa *Hall*
L. mucronata *Hall*
Productella speciosa *Hall*
Ambocoelia umbonata (*Conrad*)
Schizophoria impressa *Hall*
Pugnus pugnax *Martin*
Camarotoechia eximia *Hall*
Cryptonella eudora *Hall*
Atrypa reticularis *Linné*
Chonetes scitulus *Hall*
C. lepidus *Hall*
Liorhynchus mesacostale *Hall*
Buchiola retrostriata (*von Buch*)
Microdon bellistriatus *Hall*
Schizodus chemungensis *Hall*
Modiomorpha subalata *var.* chemungensis *Hall*
Nucula diffidens *Hall*
Palaeoneilo constricta (*Conrad*)
P. filosa (*Conrad*)
Grammysia subarcuata *Hall*
Spathella typica *Hall*
Bellerophon leda *Hall*
Orthoceras bebryx *var.* cayuga *Hall*
Gomphoceras tumidum *Hall*
Bactrites aciculum (*Hall*)
Plumalina plumaria *Hall*

There are good exposures of these beds along Trumansburg creek from ¾ mile below the Lehigh Valley Railroad bridge to half a mile west of the village. The lower beds may be seen along Taghanic creek below Halseyville, and 15 feet of fossiliferous shale are exposed below the dam at Waterburg.

There are a few field outcrops of Hatch flags on the ridge between the Cayuga lake and Salmon creek valley, and along the east line of the quadrangle, but they are all small and insignificant.

Grimes sandstones

In the Naples quadrangle the Hatch shales and flags are terminated by the Grimes sandstones, a well defined formation composed principally of thick sandstones in which several species, members of the Ithaca fauna and mostly brachiopods, make their first appearance, making the formation important paleontologically as well as stratigraphically.

The Grimes sandstones are not exposed on this quadrangle but their position is approximately indicated from exposures at the west and south.

West Hill flags and shales

This formation is composed of thin sandstones and shales having an aggregate thickness of about 600 feet. It contains a mixed fauna embracing species belonging to the Naples and the Ithaca faunas, but is but moderately fossiliferous.

The surface rocks in the southwest corner of the Genoa quadrangle are in the lowest part of this formation, but they are covered by a thin drift mantle.

For further description of the Grimes sandstones and West Hill flags and shales see State Museum Bulletin 63.

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Education Department Bulletin

Published fortnightly by the University of the State of New York

Entered as second-class matter June 24, 1908, at the Post Office at Albany, N. Y., under the act of July 16, 1894

No. 468 ALBANY, N. Y. APRIL 1, 1910

New York State Museum

JOHN M. CLARKE, Director

Museum Bulletin 138

GEOLOGY OF THE ELIZABETHTOWN AND PORT HENRY QUADRANGLES

BY

JAMES F. KEMP Sc. D.

AND

RUDOLF RUEDEMANN Ph. D.

New York State Education Department

Science Division, December 9, 1909

Hon. Andrew S. Draper LL.D.

Commissioner of Education

SIR: I have the honor to communicate herewith for your examination, the manuscripts and accompanying plates of a treatise on the *Geology of the Elizabethtown and Port Henry Quadrangles* and to recommend, if it meets your approval, the publication of these manuscripts as a bulletin of the State Museum.

Very respectfully

JOHN M. CLARKE

Director

State of New York
Education Department

COMMISSIONER'S ROOM

Approved for publication this 10th day of December 1909

A. S. Draper

Commissioner of Education

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RUDOLF RUEDEMANN Ph. D.

John M. Clarke, State Geologist

SIR: In the preparation of the present bulletin the work on the crystalline rocks has been done by the senior author and that upon the Paleozoic strata by the junior author. Geological field work in this area was begun by the senior author under the auspices of the State Museum and as a result thereof a report was rendered on *Geology of Moriah and Westport Townships, Essex county* published in 1895 as Bulletin 14. In this work W. D. Matthew was assistant. In 1894 and 1895 field work was continued in other towns of Essex county under the direction of the State Geologist, with W. D. Matthew and Heinrich Ries as assistants. These results were published in the annual report of the State Geologist for 1893, pages 433–72 and for 1895, pages 575–614. In 1896 the United States Geological Survey authorized the senior author to prepare a folio to embrace the four quadrangles Elizabethtown, Ausable, Mount Marcy and Lake Placid, all to be reduced to one map on the scale of 1:125,000. In the execution of this work the Elizabethtown quadrangle was covered during 1896 and 1897 with the aid of D. H. Newland, J. D. Irving and Charles Fulton. As a consequence of the arrangement perfected by the New York State Geologist and the Director of the United States Geological Survey these results have been transmitted to the former publication. Since the dates referred to, however, the work has been re-

vised, the iron mines carefully restudied and the area of the Port Henry quadrangle has been added, the junior author taking charge of the Paleozoic areas.

The results are herewith submitted, with the maps on the full topographic scale of one mile to one inch. Acknowledgments are cordially made to the Director of the United States Geological Survey and to the younger men who in past years have efficiently assisted in the field work.

Respectfully

James F. Kemp

Rudolf Ruedemann

Plate 1

Ruins of the old French Fort St Frederick, Crown Point. Taken in 1893

GEOLOGY OF THE ELIZABETHTOWN AND PORT HENRY QUADRANGLES

Chapter 1

INTRODUCTION

In colonial times and until a period well into the past century, the natural waterways of North America were almost the sole means of communication. First in importance among them was the great depression occupied by Lake Champlain, Lake George and the valley of the Hudson. It furnished a comparatively easy route between the St Lawrence and the Atlantic. It lay, moreover, in the debated territory between two rival colonial powers, France on the north, and England on the south. The Champlain valley was a fertile district of a character to be easily subdued by the husbandman and its situation made inevitable the result that it should be a scene of conflict and that hostile forces should sweep back and forth along its course. From the first expedition of Champlain in 1609 through the subsequent ones of Abercrombie 1758, and of Burgoyne in 1777 with the returning wave of the Continental army which followed the latter, to the naval battle in 1814, this character was asserted. Throughout all the long stretch of time thus outlined, the great stragetic position on Lake Champlain was Crown Point, within the area discussed in the present bulletin, so that the region presents not only subjects of much scientific interest but it is additionally attractive because it was the scene of the critical events in colonial history. It is the purpose of this bulletin to describe and discuss the local geology and kindred subjects; yet no one can study this region without having constantly in the background of his mind these vital facts of its early settlement and ultimate control. To the strictly scientific portion they furnish a natural introduction.

In May 1609 Samuel de Champlain entered and traversed the lake which now most appropriately bears his name. Its existence and character thus first became known to white men, and in the decades that followed, this knowledge spread among the Dutch and English settlers at the south. By 1690 the commanding situation of Crown Point was recognized in Albany and the name Crown Point was by this time current there. In 1731 the French first took definite possession of Chimney Point on the Vermont side and immediately thereafter of Crown Point itself. A palisade or stockade

was erected which was the style of fortification until 1747 but by 1750 a stone and earthwork fort mounting 20 cannon had been established and named Fort St Frederick. It was visited in the summer of 1749 by Peter Kalm, the famous Swedish traveler and naturalist, who has left for us in his quaint and fascinating book of *Travels in North America* some interesting notes on the local geology. Kalm walked about the ledges and shores both of the mainland and of the point. He noticed the same garnet sand on the beaches which we see today, and was much impressed by the specimens of Cornus ammonis or ammonites which he saw in the limestones, mistaking thus the Maclurites magnus of the Ordovicic for the index fossils of the Jurassic and Cretaceous.[1]

The French were not unmindful of the strategic importance of the headland where now old Fort Ticonderoga is being rebuilt from its ruins, and in 1755 established at this point their Fort Carillon which commanded the portage from Lake Champlain to Lake St Sacrament. Both Fort Carillon and Fort St Frederick were sources of much irritation to the colonists on the south, and finally in 1759 were captured by the British and Colonial forces under Gen. Jeffrey Amherst afterward made baron in 1776. The British then erected on Crown Point the very important fortification which still remains in a fairly good state of preservation with the exception of the old stone barracks within the earthwork. These latter are mostly in ruins. A plan of them is here given based upon a survey kindly made at the writer's request in 1908 by Mr Samuel Shapira of Witherbee, Sherman & Co., and by permission of the officers of the company. The photographs of the earthworks and barracks given on plates 2 to 5 were taken in 1897. The old for remains as a most interesting exhibition of early work of this kind. Its pentagonal outline with the salients and embrasures can be easily followed. It was obviously an undertaking of no small magnitude for its time, and is said to have cost 2,000,000 pounds. Its remains should be carefully guarded and preserved as a State or National reservation.

The old French fort, St Frederick, is much less easy to trace. The lines of its earthworks are, however, not yet fully effaced, and the reproduced photograph on plate 1 will give some idea of their distinctness. The French fort stood at the water's edge, and extended back in a salient quadrangle some 200 feet so that the

[1] Kalm, Peter. Travels in America. English translation in volume 13, page 374 of Pinkerton's Voyages and Travels. Fort St Frederick is described on p. 604–15.

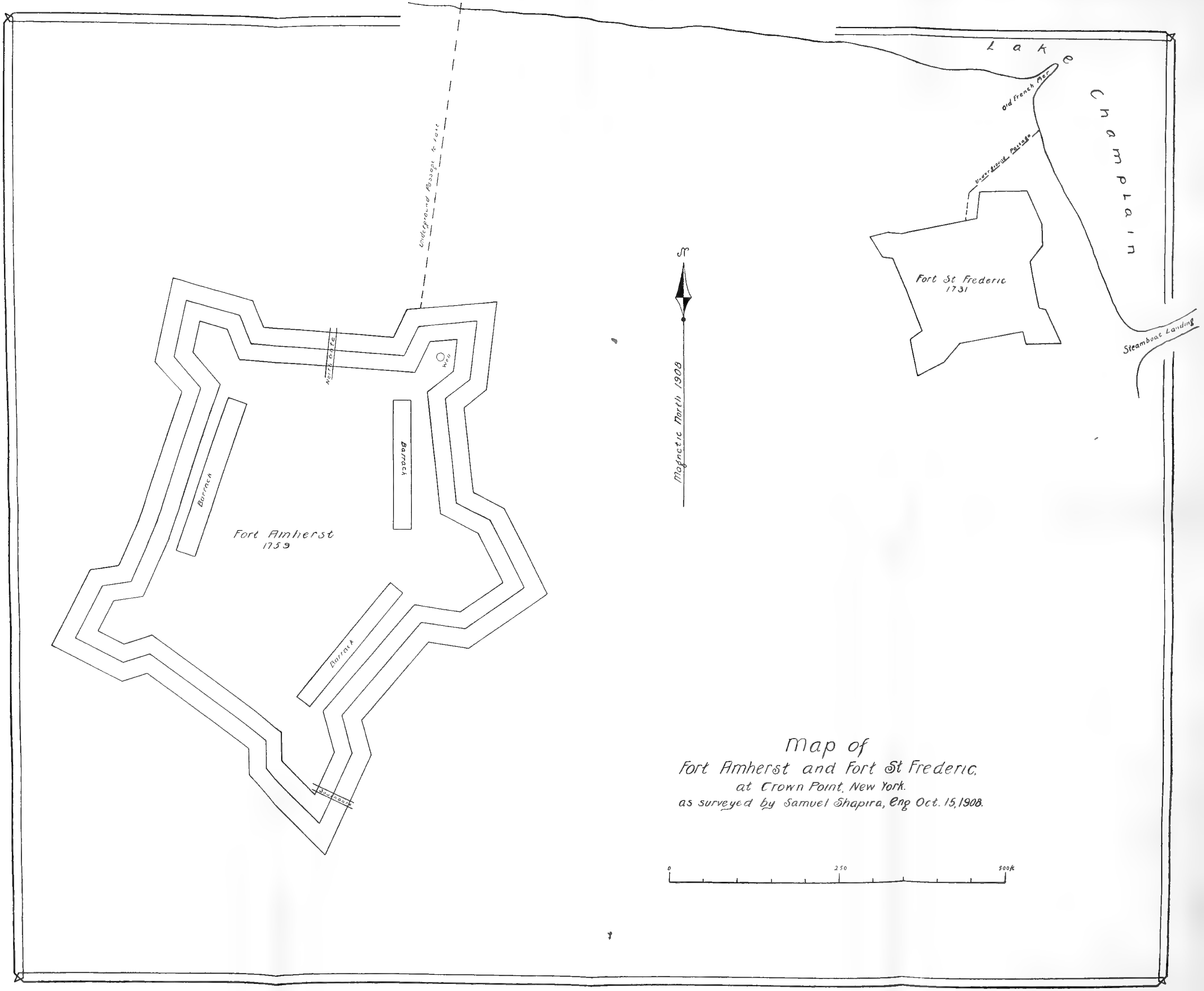

Fig. 1 Map of Fort Amherst and of Fort St Frederic at Crown Point

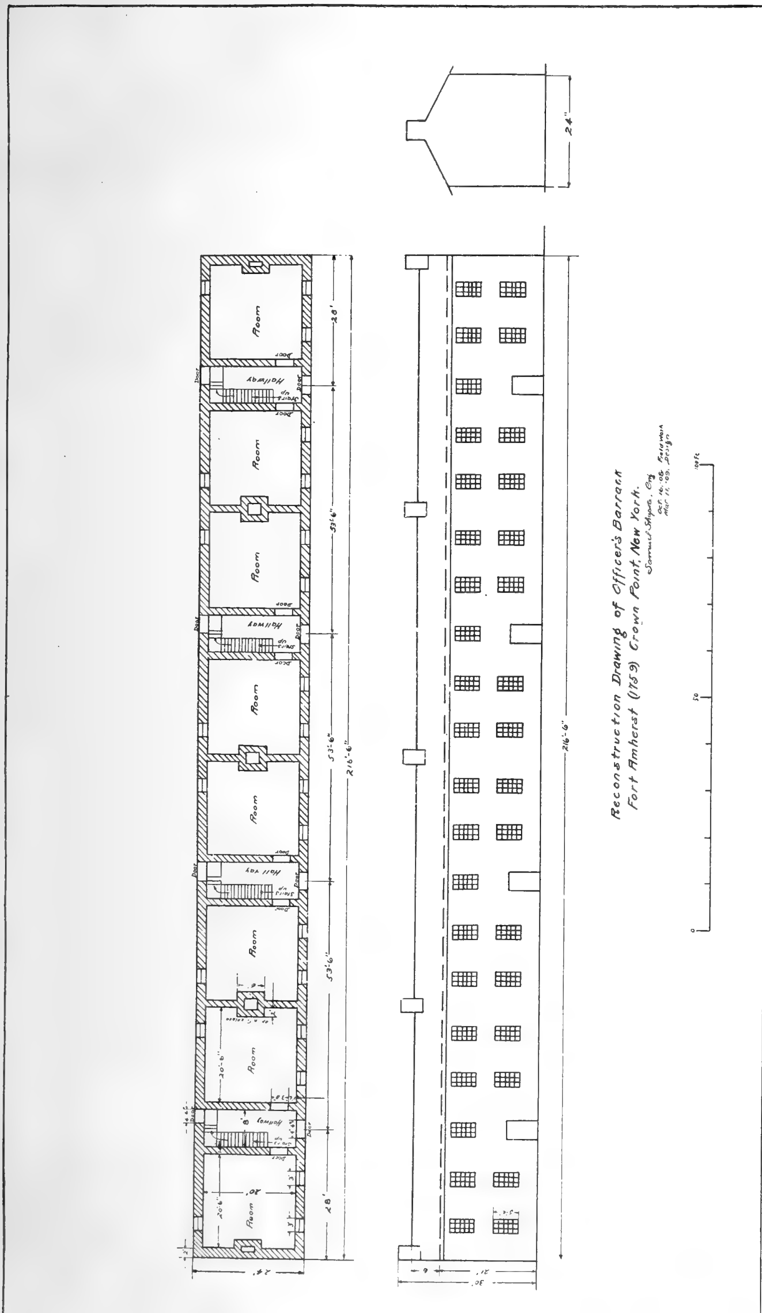

Fig. 2 Reconstruction drawing of officer's barrack, Fort Amherst (1759), Crown Point

British works which are back on the higher ground, cover some part of the site of the former. The accompanying plan of Fort St Frederick is taken from the *New Military Dictionary* 1760.

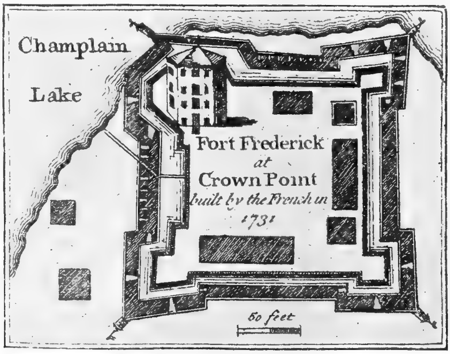

Fig. 3 Fort Frederick at Crown Point

Aside from the settlements immediately around the forts above mentioned and incident to them, peaceful occupation began in the latter half of the 18th century. It was well under way in the opening years of the 19th. Lumbering, farming and above all iron mining and manufacture all developed and became the chief occupations of the inhabitants. Lumbering has practically passed away for the time being, but the other two forms of industry, and especially those of mining and smelting are of exceptional importance.[1]

The area described in the present bulletin is contained in the Port Henry and Elizabethtown quadrangles as topographically mapped by the United States Geological Survey, in conjunction with the State authorities. The Port Henry quadrangle, lying between west longitude 73° 15′ and 73° 25′, is largely in Vermont. Only the strip included in New York is here treated. The Elizabethtown quadrangle extends 15′ of longitude westward. Both quadrangles are embraced between north latitudes 44° and 44° 15′. In these latitudes a quadrangle is approximately 12.75 miles east and west by 17.5 miles north and south. In the Elizabethtown sheet there is therefore included about 225 square miles, and the New

[1] For the general history of this region, the following are of interest: History of Essex County by Winslow Cossoul Watson, first published in the Transactions of the New York State Agricultural Society, 1852, and separately in Albany, 1869; Pictorial Fieldbook of the Revolution by Benson J. Lossing, 1860. Pages 150–51 relate to the old fort on Crown Point. One of the barracks was inhabited until just before this date. From Lossing's description they have not greatly changed in nearly 50 years.

Plate 2

View of the English fort taken from the eastern parapet, looking northwest across Bulwagga bay. The high peak on the right in the background is Bald Knob; the larger, remote one in the left background is Giant mountain.

Plate 3

View of the parapet of the English fort looking south through the embrasure to the southern and best preserved barracks

Plate 4

View of the English fort looking east from the west parapet

Plate 5

View of the best preserved of the barracks, from the north

York portion of the Port Henry is approximately 68, making a total of 293 square miles. Both sheets lie in the fourth tier from the International boundary and the southern limit is approximately 115 miles from Albany. The area lies entirely in Essex county. The lagest town is Port Henry which is the business center. At the last census it was credited with 1751 inhabitants. The number fluctuates with the activity of the local blast furnace. Mineville, including Witherbee, 5 miles to the northwest, is second. Its population is about the same but it also varies with the operations of the great iron mines. The town of Moriah, which contains them both and other smaller villages, had 4447. Westport town was credited with 1727 people and Elizabethtown village with 491. Both are essentially dependent upon the local agriculture and the summer visitors, with whom both are justly popular. Wadhams Mills has an important water power and electric installation, but the other local aggregations of people, Moriah Center, Moriah Corners, and New Russia are smaller. Back from the lake the rest of the area, except for an occasional farm along the highways is largely a forested series of hills and mountains, broken by precipitous escarpments, extremely rough in their relief. Only two highways cross the 17.5 miles of the western border and of these the northern one is alone much traveled. The southern one, from Underwood to the Keene valley by Chapel pond is none the less one of the finest drives in the mountains.

Along the lake, in the flat forelands, the farms extend continuously and are located upon a level and easily subdued surface. The scenery, embracing as it does this combination of wild mountains and cultivated lands, is of great charm and beauty. The view from Bald Knob commands the valley of Lake Champlain as far as the eye can reach, the distant range of the Green mountains, and the high peaks of the Adirondacks, 30 miles to the westward. It is thus one of the most comprehensive in the mountains and in its physiographic features one of the most suggestive and instructive in the East. No observer, unless dull and unimpressionable beyond belief, can leave it without fairly wrenching himself from its contemplation by force of will, exercised because of the unavoidable pressure of other duties.

Chapter 2

PHYSIOGRAPHY

The lowest point within the area is the surface of Lake Champlain. This varies through several feet between conditions of high and low water but it ranges so near 100 feet above tide, that this

number, so easy to remember, may be established in mind as a datum.

The charts of the survey show by the soundings depths for the lake ranging down to about 400 feet, as a maximum. The deepest portion is opposite Essex and just north of the present map. The deepest point upon the map itself is 334 at the northern end and near the New York shore. A pronounced channel follows along the western side of the lake of varying depths above the maximum to 257 as a minimum before Westport is reached. Off Westport 201 feet have been found. Off Barbers point the depth is 191; off Coles bay 166; a mile and a half south 100; then from 50–60. The deepest near Port Henry is 53. In the Chimney Point passage it is 55, and then farther south less than 30. Undoubtedly the deposits of drift and of Champlain clays mask the natural outline of the bottom. The rocky bed ought to slope downward all the way to the St Lawrence river, although it may be somewhat modified by postglacial warping.

The highest point within the area is Giant mountain at 4622 feet.[1] Thus from the bottom of the lake to the loftiest mountain there is a range of just about 5000 feet. Giant stands a little north of the middle of the western border, and is the eighth in altitude of the loftier Adirondack summits. It forms the culminating point of a group or massif, and has a steep eastern front at the head of an amphitheater. Rocky Peak ridge, one of its buttresses, reaches 4375 but is hardly to be considered a separate mountain. Giant is chiefly ascended from the Keene valley. The trail from Elizabethtown has in later years become obscured. The Keene trail involves a long walk through the woods, until quite suddenly the summit is reached. North of Giant and fairly distinct from it is Green mountain a great east and west ridge attaining 3928 feet and having for its spurs, Tripod, Knob Lock and Cobble.

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[1] By way of comparison a summary of the most elevated peaks may be of interest. They are in order.

	Feet		Feet
1 Marcy	5 344	9 Nippletop	4 620
2 McIntyre	5 112	10 Redfield	4 606
3 Skylight	4 920	11 Saddleback	4 530
4 Haystack	4 918	12 McComb	4 425
5 Whiteface	4 872	13 Sawteeth	4 138
6 Dix	4 842	14 Cascade	4 092
7 Gothics	4 738	15 Porter	4 070
8 Giant	4 622	16 Dial	4 023

No others reach 4000 feet. These altitudes are taken from the topographic maps.

In the northwestern corner is Hurricane mountain, at 3687 feet, the most prominent peak in this section, and one frequently ascended from both the east and the west. In the southwestern corner there is another group of relatively lofty summits, eastern outliers of the Dix massif. Spotted mountain at 3480 is the culmination. They are seldom climbed.

In the central portion of the area the summits are less exalted and yet a number stand out in prominent relief. Raven hill at 1967 near Elizabethtown is more pronounced than its mere altitude would indicate. The open country lying east of it adds to its effectiveness. Broughton ledge with its precipitous southern side, which is not properly shown by the contours, is another marked topographic feature. Harris hill, 2190, is a very characteristic anorthosite dome, and Blueberry hill at 2323, a sharp inverted wedge, is the most decided landmark in this section. For the broad expanse of view and the varied scenery, Bald knob, at 2055, is unrivaled, and is the striking summit which catches the eye of the traveler on Lake Champlain. The attractive and instructive panorama, commanded by its summit, has already been mentioned.

If we seek uniformity or marked relationship in the shape and arrangement of the elevations, we find their distribution not so simple. Yet some striking features can be identified to which more extended treatment may be given subsequently. Thus from Giant to the south and southeast almost all the structural lines are northeast and northwest. The same feature can be followed across the northeastern corner of the Elizabethtown quadrangle, and is pronounced in the Split Rock range. It is also recognizable but more faintly in the Hurricane massif and its outliers.

By contrast, the valley of the Branch which gives the pass for the highway from Elizabethtown to the Keene valley is almost due east and west, and the very marked valley of the Boquet from New Russia to Elizabethtown is almost north and south. Green mountain is roughly east and west, as are Broughton ledge and the unnamed ridge next north. The Bald knob ridge trends north and south and is abruptly cut off toward the lake by the great escarpment, undoubtedly a fault line, which runs from Bulwagga mountain on the south as far as the latitude of Westport. There are thus these less emphatic and easily recognizable features which may be relics of older conditions.

The lowest point along the shores of Lake Champlain is naturally its surface at 100 feet, but the shore line enables one to see at a glance the character of this portion of eastern New York. Ridges

run down to the lake from the southwest forming mountainous escarpments around whose sides the Paleozoic rocks set back in embayments and between which they constitute flat forelands, obviously the western remnants of the level expanses of the Vermont shore. Within the area here mapped there are the Port Henry and Westport embayments, and in addition the northerly prong of Crown Point. Farther south the same relationship reappears in Ticonderoga, and farther north it is very emphatic in Essex and Willsboro. The village of Port Henry is built on a small flat at 240 contour, while the large level stretch southwest of Westport ranges up to the 300 as a maximum. Beyond question these flats are fault blocks.

Escarpments. The relief of the mountains and valleys can hardly be dismissed without mention of the escarpments. They are at times very pronounced. In fact the favorite outline of the eastern Adirondacks is the sawtooth. As the observer follows the sky line from any point of outlook commanding a wide sweep, he can not but be impressed with the moderate upward slope of one side of a mountain, terminating in a sharp, precipitous cut-off on the other. Usually the moderate slope follows the dip of the foliation while the precipitous side is due to a fault. Upon the topographic maps the abrupt character of the escarpment is much softened by the spreading of the contours either on the part of the draftsman or the engraver. Thus the Broughton ledge [pl. 6], 4 miles west of Moriah Center is a sheer cliff two or three hundred feet, almost smooth and scarcely 5 degrees from the vertical. Others of impressive steepness front the road from Underwood past Chapel pond on the northeast side, and many smaller cliffs are on the northwest side of the road which follows the Boquet river to its source south from Elizabethtown. In several instances trap dikes have come up through the cleft which has caused the cliff and portions may remain adhering to the sides of a precipice. One such may be observed along the northwest side of New pond, and another in the cliffs just north of the brook, which reaches Pleasant valley from the north side of Iron mountain. The dikes are shown on the geologic map.

These cliffs are constantly met in traversing the mountains and are often encountered in passing through the woods on the steeper slopes. They make constant detours a necessity. When, moreover, one reaches the summit of a ridge and proceeds along its crest, the way is interrupted constantly by cross-gulches with precipitous sides, through which either a human or a game trail almost always

Plate 6

Broughton ledge, western Moriah; a fault scarp

passes, and in whose bottoms, small isolated swampy places with specially interesting flora may be found. If the northeast ridges from 4 to 7 miles west of Mineville, as shown on the map, are selected and the contours critically observed these features come out strongly. The little isolated dells amid the higher mountains present extremely picturesque spots with often the track of a deer or even the footprint of a bear in the mud.

"The Gulf." At the extreme southern edge of the Port Henry quadrangle and in Bulwagga mountain, there is a deep gorge of extraordinarily short length for its depth. It is one of the most remarkable physiographic features of the entire area. Although on the map a little forking brook is shown coming down from it into the Ticonderoga quadrangle to the south, the amount of water is very small and altogether insufficient to have produced the depression.

Bulwagga mountain is more of a plateau than a mountain summit. Near the head of the gorge it stands at the 1000 to 1100 contour. Suddenly and far more abruptly than the contours on the map indicate, the surface drops three or four hundred feet precipitously away to the eastward. From the projecting spur of Bulwagga, which bounds it on the north side and which reaches a little higher than the 1200 foot contour it must be 600–800 feet to the bottom of the gorge. The entrance to the gorge is quite flat at about the four or five hundred foot contour. To the east the slope drops off with a moderate gradient to the 1401 foot level of the Paleozoic floor. Attempts to get pictures from the upper edge were not very successful as the drop is too abrupt for a camera to take in a significant view. The whole physiographic form and relations remind one of the barrancas of the Mexican plateau in the State of Vera Cruz, and elsewhere. In the Mexican region the streams have eaten back with surprising rapidity into the plateau and their valleys fall away with great abruptness, but in the case of this gorge, there is no water adequate to the task. We must conclude that a small lobe of ice in the closing, and perhaps also in the opening glacial epoch, ate back into the mountains and developed a cirque, on a small scale. The practically precipitous slopes can thus be explained. The bottom is now somewhat disguised by the blocks which have fallen in, and no rock basin and pool such as should exist in a typical cirque are visible. The master joints run n. 40 w. true, and coincide with the axis of the gorge. Some such line of weakness must have located it

originally. The subsequent sculpturing then developed its present form.

From the outlook tower at Cold Spring park on the south one looks into the gorge, but from the summit on the north side the most impressive view is obtained.

Drainage. The larger features of structure which have just been remarked in the review of the physiography have been the chief factors in locating the lines of drainage. The glacial deposits have in a minor but still recognizable way also exercised an important influence.

The chief streams are two, the Schroon river which drains the southwestern portion and which passes to the Hudson; and the Boquet and Black rivers which drain the western and northern portion, combining as the Boquet, to enter Lake Champlain. Between the Schroon and the Boquet, Mill brook with its mouth at Port Henry and Hoisington brook at Westport are the chief streams. Along the shore, however, a number of additional but smaller ones run from the mountains directly into the lake.

The Boquet river after its junction with the Black and after some meanders across the drift, leaves our map at the 270 contour. The Schroon river is higher and passes to the southward just below the 900. The divide or col between the two stands at 1130 feet. The divide is a rather important one in that it marks the boundary between the St Lawrence and the Hudson drainages. Roughly speaking about one fifth of the area discharges through the Schroon river to the Hudson; the remainder sends its waters to the St Lawrence.

At the headwaters of both the Schroon and the Boquet are some extremely interesting features which also extend into the neighboring quadrangles. The marked northeast and northwest structural lines have caused even the little brooks to follow them. We may start at the source of some little tributary, such as the Moss ponds, southwest of Underwood, and follow the stream around three sides of a rectangle, each turn being a sharply angular one.

This peculiar arrangement of the streams, although observed by the writer at the outset of field work, also independently attracted the notice of Prof. A. H. Brigham during a study of the maps, so that the first mention of it in print is from his pen in an article entitled "Note on Trellised Drainage in the Adirondacks" in the *American Geologist*, 1898, volume 21, page 219.

The trellised drainage is believed by the writer to be due to a pronounced system of block faulting which has broken up the

country into these marked divisions, and which by sheeting the rock along the lines of movement has produced the vulnerable portions, searched out by the moving water. Aside from the evidence of the topography the inference is corroborated by the exposures afforded in these and neighboring quadrangles by the waterfalls of which there are a few. Thus at Split Rock falls in the Boquet river about 7 miles southwest of Elizabethtown, the old crystallines are sheeted and crushed in a most significant manner. Precipitous escarpments display the same characteristics and yield often great talus slopes of angular blocks with parallel sides. The localized and close set grouping of the planes of separation irresistibly suggests to the observer a fault line or zone rather than the simple record of joints which of themselves are not easy to understand except as composite faults of slight individual displacement.

Of the geological date of this fault system it is difficult to form an estimate. The youngest rocks affected are Cambric and Ordovicic. The freshness of the relief would suggest a time possibly in the Tertiary, but undoubtedly the plucking of the Continental ice sheet and of local glaciation freshened up the relief very greatly, by the production of bergschrunds.[1]

In the Paradox Lake quadrangle just south, Dr I. H. Ogilvie[2] has detected flat-topped mountains which strongly suggest remnants of an old peneplain, now broken into blocks by faulting. If this peneplain marks the completion of the Cretaceous cycle of drainage as is not improbable, the faults would be of Tertiary date. The suggestion is however but a surmise and, as is always the case with faults in the ancient crystalline rocks, the evidence is less easy of attainment than in the stratified rocks with their contrasted beds and fossils.

Besides the northeast and southwest systems of drainage just described there is in this quadrangle and still more in neighboring ones evidence of north and south valleys, and of east and west ones which are older. The latter are broader and more open; their

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[1] Bergschrund is the word current in Switzerland for the space or chasm which customarily intervenes between a glacier and the rocky walls of the valley through which it moves. It is a place of specially active removal of rocks because in the warmer seasons the ice melts by day from the sun and the water freezes again at night from the cold. Glaciers thus gradually widen their valleys and render the sides very steep. There seems to be no good English equivalent for bergschrund—therefore it is adopted as above.

[2] Geology of the Paradox Lake Quadrangle. N. Y. State Mus. Bul. 96. 1905. p. 468.

sides have gentle slopes and show evidence of much more protracted wasting away. The best example in the Elizabethtown quadrangle is the valley of the "Branch" which enters the Boquet at the village itself. Although the Branch is the smaller stream, its valley, except perhaps at the headwaters, is more open and larger than that of the Boquet itself. From observations on a wide area the writer has therefore been impressed with the probability that the oldest drainage lines were east and west, and north and south. They often correspond with belts of Precambric limestones which furnish comparatively soft and easily eroded rocks, and the resulting topography has a different aspect and character from the precipitous northeast and northwest valleys. The Elizabethtown quadrangle does not furnish however the best evidence and therefore the subject is not further pursued at this point. The citations below will place the reader in touch with the fuller literature so far as it exists.[1] Nevertheless, in the southern central portions of the quadrangle there are two escarpments which run nearly due east and west. One, the Broughton ledge, a most impressive precipice, illustrated in plate 6, and the other less steep, rise on the north side of Crowfoot pond in a series of steps.

Aside from the small feeders or tributaries which have high gradients and cascades, the larger streams are usually marked for a mountainous region by low gradients and slack water until they drop with relative suddenness to Lake Champlain. For example, in a distance of ⅞ mile from Split Rock falls to a point below Elizabethtown the Boquet river meanders for 7 miles through open meadows. Its descent is chiefly concentrated at New Russia, where there is a drop of 40 or 50 feet within less than half a mile, and partly over ledges. Both at Split Rock falls and at the cascades at New Russia the river presents the relationship not uncommon in the Adirondacks, of a waterfall succeeded by an open and level valley, containing a sandy lake bottom or meadow land which the stream next traverses. The Schroon is also a very sluggish stream with a relatively low gradient. Other smaller streams, such as the outlet of Lincoln pond and Ashcraft brook are decidedly swampy.

These relationships are undoubtedly due to the postglacial ponding back of the waters either by the retreating ice sheet on the north or by moraines which for the time furnished a barrier. In

[1] Kemp, J. F. Physiography of the Adirondacks. Popular Science Monthly. March 1906. p. 199; Ogilvie, I. H. Geology of the Paradox Lake Quardrangle. N. Y. State Mus. Bul. 96.

Plate 7

Bartlett pond near Mineville, filling a hollow in glacial drift. Drift-covered landscape. Giant mountain on right in background; Mt Dix left center. View from Bald Knob

the valley of the Boquet the lake was created whose abandoned bottom now yields the meadows of Pleasant valley. This lake bottom was described by Heinrich Ries in 1893.[1] The ponding back of the waters was discussed four years later by F. B. Taylor.[2] Down stream and in the northeastern edge of the Elizabethtown sheet, there is a morainal barrier which is now cut through. Its top is on the 500 foot contour while the stream flows at 400 feet. This is not quite high enough for the Elizabethtown bottom at 540–60, but it would account for some of the phenomena in the southwestern portion of the Ausable sheet, where lake bottoms are beautifully developed. The Elizabethtown lake bottom has gone to the extent of arable meadows but the one which lies along the outlet of Lincoln pond and which doubtless marks its former extent, is still in the condition of swamp. It is a not uncommon experience to note other little abandoned lake or pond bottoms, too small to be brought out very strongly by the contours, but furnishing a stretch of meadow land or of a small farm. Within the area of the sheet almost all of the stages from lake or pond to meadow, which have been graphically described by C. H. Smyth, jr,[3] can be identified and the significance of these minor features is so plain as to easily attract and impress even the casual observer during drives for pleasure.

Deltas. In no other form of evidence is the effect of the postglacial ponding so clearly indicated as the deltas, and that too immediately beneath a portion of Elizabethtown itself. The flat or terrace shown on the map at the 600 contour and lying in the southwestern portion of the village is a particularly fine example and is almost a dead level. It has furnished the site for the Windsor and Antlers hotels and for the county buildings. Undoubtedly it was built up by the Branch and its upper portion has probably wasted away but little in the time since its construction. It stands quite 40 feet above the lake bottom of Pleasant valley and the 600 foot contour is not cut by the Boquet until we go 3 miles or more to the south at the New Russia cascade. In August 1893 there was a very sudden and heavy storm in this section of the mountains which produced such floods that bridges were carried off and the banks were undermined throughout this and neighbor-

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[1] Ries, Heinrich. A Pleistocene Lake Bed at Elizabethtown, N. Y. N. Y. Acad. Sci. Trans. 1893. 13:197.

[2] Lake Adirondack. Am. Geol. 1897. 19:392.

[3] Smyth, C. H. jr. Lake Filling in the Adirondack Region. Am. Geol. 1893. 11:85.

ing valleys. The Branch cut away the delta face and gave particularly good exposures of which the writer, fortunately in the field at the time, obtained the photograph shown in plate 8. The cross-bedding and the upper horizontal beds both come out very clearly.

This terrace has been the scene of one of the ill advised placer-mining excitements which spread periodically through the mountains. It was prospected by pits in 1895 for supposed gold and platinum.

At the mouth of Roaring brook, just north of New Russia, there is another fine delta terrace placed on the map at a little below the 600 foot contour, but the difference is not great and its upper level was doubtless due to the same hight of water as the one at Elizabethtown.

Along the Schroon river and just west of Holiday pond there is an extensive gravel terrace with pebbles up to 2 inches, and with its top at the 980 foot contour. There must have been ponding of waters at this locality, higher than the Elizabethtown level of 600 feet and the pebbles are so coarse as rather to argue delta conditions, than a lake bottom. The ponding may have been conditioned by a temporary ice barrier. Still farther south a terrace is again pronounced between 940 and 960, where the highway crosses and leaves the sheet. The difference in altitude between this one and the one to the north is not great and they may have been the result of the one hight of water.

Stream terraces. At several places stream terraces are beautifully shown. In the southeasterly oxbow of the Boquet river, in the northeast corner of the Elizabethtown sheet, extending into the Ausable sheet to the north are four terraces, respectively at 8, 18, 22 and 40 feet above the creek, which is here at the 400-foot contour. An additional indistinct one is half way between the 8 and 18 foot ones. Again along the Schroon as it leaves the southern edge of the sheet, there are four terraces, respectively at 894, 900, 920 and 940 feet. Both of thse are due to the meanders and downward cutting.

Sand dunes. In the extreme northeastern corner of the Elizabethtown quadrangle and in the point of land between the Boquet and the Black rivers, there is a very sandy area marked by small drifting dunes and by interesting wind-blown phenomena of this character. Ripple marks appear over a portion of the sandy expanse. The whole aspect irresistibly suggests the seashore.

Plate 8

Postglacial delta cut of the "Branch" near Elizabethtown, freshly exposed at time of flood, August 1893

Chapter 3

GENERAL GEOLOGY

Grenville series

Introduction. Far the greater part of the area consists of the ancient Precambric rocks, a very complex group, which, however, can be deciphered into several recognizable and distinguishable components. Along the shores of Lake Champlain in embayments or projections extending from northeast to southwest up into the valleys between the ranges which come down to the lake, are found the Paleozoic sediments, beginning with the Potsdam sandstone and ending with the Utica slate. One dike of igneous rock has been found, which cuts the Paleozoic strata. Some miles west of the Champlain valley and separated from the main Paleozoic exposures, one outlier of Potsdam has been discovered and there are indications of a second, 1½ miles west of Elizabethtown, although only loose float has been seen. The Precambric rocks are usually metamorphosed and are in instances much changed from their original condition. The Paleozoics are not greatly recrystallized and are much contrasted with the older formations. The two can well be treated separately and, as here, by different writers.

Precambric formations in general. The Precambric complex is separable into an older sedimentary portion and a later igneous portion. The sediments occupy far the lesser area, and must be but a fragment of what was originally a widespread series, which has been invaded, broken up and metamorphosed by the eruptives. In fact one can only gain a comprehensive grasp of the total geology by picturing a sedimentary area penetrated and overwhelmed by a vast igneous outbreak. We have, however, only the deep seated rocks. There is reason for believing that the overlying volcanics which probably accompanied them were all worn away long before the Potsdam epoch opened. With them went also undoubtedly a vast amount of the ancient sediments. The grounds for this belief are, the relatively small amount of the sediments now remaining; the deep seated character of the eruptives; and the need of assuming some load now gone, beneath which these igneous rocks could crystallize in their present coarseness of grain. It is also conceiveable as an alternative that the igneous rocks were altogether intrusive, and that there were enough sediments over them to supply the pressure and the conditions of slow cooling. We can only contrast the two possibilities since no actual trace of one remains more than of the other.

The Precambric rocks are classifiable in order of age from the latest to the oldest as follows:

The unmetamorphosed basaltic dikes

The eruptive complex of more or less metamorphosed granites, anorthosites, syenites, gabbros and intermediate types.

The Grenville series of limestones, ophicalcites, schists, and sedimentary gneisses

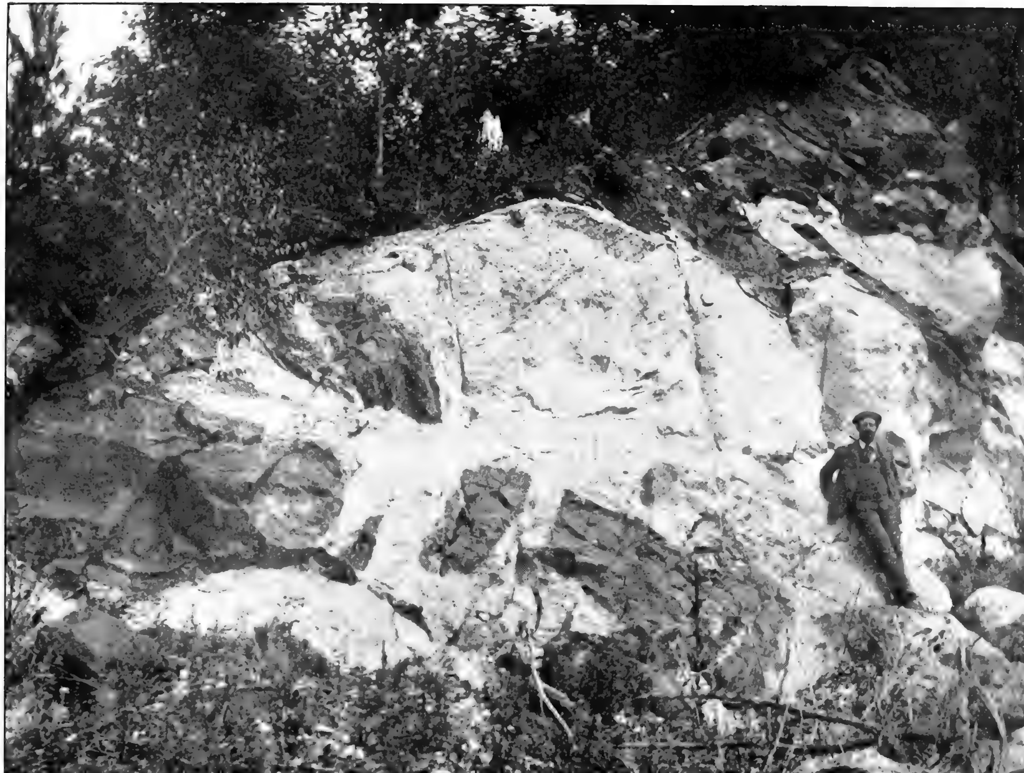
Grenville series. The name Grenville was originally given by Logan to a series of rocks in all respects similar to the one here under discussion and developed in the township of Grenville, Ontario. Ebenezer Emmons in his early work in the Adirondack area spoke of them as primary, and, under this head, placed the limestones (called primitive limestone) and the serpentine with the igneous rocks, while the gneiss was classed with the stratified. It is one of the curious instances of the changes in geological thought, that 60 years later these views are exactly transposed. In later years the wise custom has developed of applying geographical names to formations and for this reason the term Grenville is here adopted. It is true that a gap intervenes between the Adirondacks and the Canadian exposures in Quebec and Ontario, and that this gap is covered by the Paleozoics, but the similarity of the old sediments in both areas is so great, that there seems little doubt that they are equivalents. The International committee, which visited both regions in 1906 and submitted a report on the correlation of the two were at least sufficiently impressed with the similarity to recommend the uniform use of Grenville.[1]

The Grenville strata are widespread in the Adirondacks, scarcely a quadrangle being without them. On the Port Henry sheet and along Lake Champlain just north of Port Henry is one of the best exposures in the eastern mountains, but they also appear at a number of other localities in the area here described.

The most prominent and easily recognized of the members is a white crystalline limestone, very coarse grained and seldom pure or uniform over any great width. It is marked by small inclusions of pyroxene, graphite and less common individual minerals and by larger streaks and pegmatitic aggregates of coarse quartz, feldspar, hornblende, biotite, tourmalin, titanite, pyrrhotite and scapolite. Where the limestone has been quarried for fluxing purposes in the iron furnaces, as has been the case near Port Henry, large dumps of the rejected silicates have accumulated, and now afford

[1] Jour. Geol. 1907. 15:191.

Plate 9



Faulted dike, now hornblende schist, in limestone; near Pilfershire mines

interesting material for the mineralogist. This limestone is a fairly pure calcite.

Overlying the limestone stratum at Port Henry there is another of ophicalcite, or of limestone speckled with included masses of serpentine. This stone has been the object of quarrying and, furnishing as it does, a variety having a white base with light and dark green mottlings distributed through it, has commanded some attention as an ornamental stone under the name of verde antique, or Moriah marble. The serpentine is believed to be due to the hydration and alteration of original diopside, whose unchanged cores may be sometimes detected within the mass of serpentine.[1] This is practically the same rock as that which furnished the Eozoon canadense, to the early observers, but no good specimens of this exploded organism have been discovered.

A very characteristic minor associate of the limestones is a lemon-yellow quartzite or quartz-schist, with more or less disseminated graphite. The yellow color is doubtless due to decomposing pyrites and the rock will often yield the astringent taste of iron sulphate.

Black and coarsely crystalline hornblende schist is also a common associate of the limestone but in relatively small amounts. It may contain large red garnets. The observer is often puzzled whether to interpret this rock as an altered intrusive mass of gabbro or as a metamorphosed sediment. There are probably cases of both. The remarkably regular masses which cut across the exposures, and have a uniform and moderate thickness suggest an intrusive origin most strongly of all. Over the Pease quarry just north of Port Henry there is such a black band, and one courses through another quarry in Pilfershire, southeast of Mineville. Along the Delaware and Hudson railway tracks on the lake shore north of Port Henry where there is an irruptive contact of gabbro and basic syenite and limestone one can see the igneous rock tonguing out into the limestone and apparently pinched off at times by the dynamic disturbances. While it is entirely possible that the hornblendic rocks have been derived from aluminous bands in the original sediment, which might yield greater or less amounts of hornblende, yet we are dealing with a district in which are numerous intrusions of gabbro and basic syenite and where apophyses are abundant. The marked plasticity of the limestone under pressure

[1] Merrill, G. P. Notes on the Serpentinous Rocks from Essex Co., N. Y. etc. U. S. Nat. Mus. Proc. 1890. 12:595-600.

tends greatly to disguise the relationship and to render a demonstration difficult. Igneous phenomena and their expiring effects must have been very general and have probably occasioned widespread recrystallization. Undoubtedly they have set in migration many heated solutions.

The limestone becomes at times extremely small in amount and may be represented by little more than calcareous streaks amid more siliceous rocks, such as mica schist and quartzite bands. The whole may be folded in a most remarkable way. The more resistant silicates having been involved in a plastic medium like calcite have been bent into shapes that seem almost beyond the power of brittle minerals to assume. The presence, however, of the limestone is indicated by the pitted and cavernous weathering.

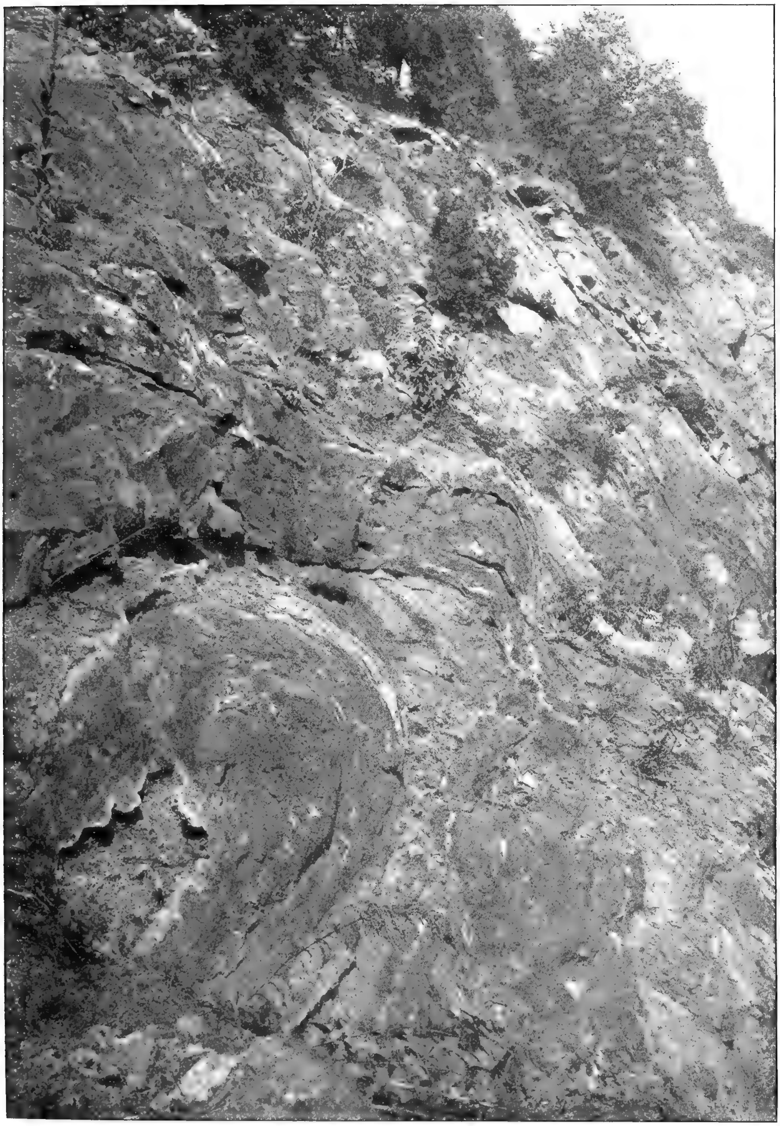
Mica schist or schistose gneisses are known in several localities which also represent the sedimentary series. The rocks are thinly laminated and are much more abundantly provided with biotite than are the eruptive gneisses. The banding runs regularly for greater distances and reproduces the persistent bedding of sediments rather than the sheared and dragged individual minerals of the eruptives.

Besides the more schistose gneisses there are others less thinly or regularly banded and yet not corresponding exactly to any of the well defined eruptive rocks. Where they display sharp contrasts of light and dark bands which are persistent over distances of several feet or more and which are difficult to explain except on the basis of the contrasts in composition which might arise in sedimentation, the writer's disposition has been to group them with the sedimentary types. It is realized that eruptive rocks themselves do display marked banding and gneissoid structures which are due to magmatic differentiation,[1] but yet in open questions like those presented in the Adirondacks, as a matter of opinion the writer leans rather to the sedimentary interpretation especially when the rocks are associated with undoubted sediments.

Some complication arises because of the abundance of pegmatitic matter even on a small scale. Injected gneisses are not unknown and inasmuch as such quartzites as can be recognized in the region are so thoroughly recrystallized as to simulate vein quartz or pegmatitic quartz, lenticular masses of this character may at times give rise to the suspicion of old sandstones. Well defined quartzites are, however, much less in evidence in the two quadrangles under discussion than in several to the south.

[1] As very clearly shown by Sir Archibald Geikie and J. J. H. Teall for the gabbros of Skye. Geol. Soc. Lond. Quar. Jour. 1894. 50:645.

Plate 10



Folded interbedded schist in Grenville limestone, along the Delaware & Hudson Railroad, north of Port Henry

Plate 11

Grenville limestone along Delaware & Hudson Railroad, north of Port Henry; charged with streaks of silicates and weathered

In the Paradox Lake quadrangle which lies next south of the Elizabethtown and also in the Whitehall, which is southeast of the Paradox Lake, there are extensive developments of a richly garnetiferous, green gneiss, often with much sillimanite. None of this has been observed in the Elizabethtown-Port Henry area. Its original is believed to be a somewhat calcareous shale and it is characteristically associated with the graphitic schists or quartzites which are the commercial sources of graphite. Its absence would argue some change in the character of the Grenville sedimentation to the north, presumably to more purely siliceous or feldspathic materials, whose metamorphic derivatives lack both the lime and the carbonaceous components.

In addition to the above, which may be considered fairly well defined sedimentary types, there are great masses of decidedly gneissoid rocks, usually granitic or at least quartz-bearing in composition, with hornblende and augite as the common dark silicates and with coarse crystallization. They are well shown in the ridge of Bald knob and they are extremely difficult to interpret. The writer's disposition is, on account of mineralogical composition and associations to regard them as igneous in character. They are placed with the syenite series as an acidic extreme. It is realized that another observer might develop a strong argument for their sedimentary characters. It is felt that the best course is to fully and fairly state both cases hereafter.

Chapter 4

GENERAL GEOLOGY (*continued*)

Metamorphosed eruptives

This group is contrasted with the next one of the unmetamorphosed basaltic dikes, because the latter are obviously much later and because they followed the period of metamorphism and crushing, presumably also of extensive erosion, to which the former were unquestionably subjected. At the same time it is believed that the dikes are older than the Potsdam and that they belong to an entirely different set from the ones which penetrate the Paleozoic sediments[1] in adjacent areas.

The older eruptives with the possible exception of some exposures of the basic gabbros constitute extended and huge masses

[1] See in this connection the following paper by H. P. Cushing who was the first to show the distinction between the two groups. On the Existence of Precambrian and Postordovician Trap Dikes in the Adirondacks. N. Y. Acad. Sci. Trans. 1896. 15:248.

of plutonic rocks. They are batholiths or great, deep seated volume, of irregular shape. The included fragments of older rocks which have from time to time been detected demonstrate their intrusive nature. These and the nature of the intrusive contacts give such clues to their relative ages as can be obtained. The original outlines of the intrusions, that is, the evidence as to whether they ever assumed the laccolithic or other definite shapes, have been rendered wellnigh undecipherable by faulting and erosion.

Granites and related types

There are several areas to which this name has been distinctively applied. While they are described before the anorthosites and other eruptives their relations to the latter are obscure. In general they are believed to be older, but there is little ground for this belief other than their intimate association with the Grenville. Their distinction from the acidic members of the syenite series is, moreover, not in all cases clear; and the possibilities of the occurrence of shales and feldspathic sandstones in the Grenville, which might yield, upon extreme metamorphism granitic gneisses, have not been overlooked. Nevertheless both in the field and in the laboratory the occurrences here colored and described as granites, have impressed themselves as sufficiently distinctive to justify the procedure.

The largest area is in the southeastern corner of Bulwagga mountain. A biotite granite is very abundant all through this portion of the sheet, so much so as to be the predominant rock. While it may not be the exclusive member, the variations can not well be shown in colors. Excellent exposures appear near the iron bridge at the headwaters of Grove brook. In their section microcline is the most abundant mineral while quartz and biotite practically complete the slide. This combination is in contrast with the mineralogy of the other groups of eruptives. Both microcline and biotite are seldom seen in the latter, and the inference is natural that when they predominate we are dealing with a separate intrusive.

In the western portion of the area colored green, red granitic rocks have been observed, which reveal under the microscope no dark silicates, but which have only finely striated plagioclase and quartz. A few decomposition products, perhaps from dark silicates, and a few tiny zircons complete the slide.

Throughout this granitic area much pegmatite is present and the granites are often cut by it.

About 3 miles north of Port Henry another area of small dimen-

sions appears on the east and west road. To the observer in the field this appears like a pronounced intrusive granite, sheared more or less into a gneiss, but different from both the syenite series and the Grenville. The microscope reveals quartz, microcline, microperthite and hornblende. It is, therefore, not so sharply contrasted with the acidic members of the syenite series as is the Bulwagga occurrence, in that it has microperthite and hornblende, but it has microcline and in the ledges it looks unlike the syenite series.

There are two other small areas colored for granite, and lying southwest of Westport. Both of these are coarse gneisses, reddish in color, with their quartz and feldspar in little, interleaved lenses, up to an inch in length. No microscopic slides have been prepared and the rock might perhaps be justifiably placed with the syenite series. In the field it was believed to be different.

Besides the occurrences actually colored, there are one or two others deserving mention. In the gorge of Mill brook, just north of Port Henry, and a short distance above its mouth, there is a band of white granitic rock, several hundred feet thick, in the midst of the Grenville limestones. It is obviously much crushed, is dense, white and granitic in aspect. Under the microscope its components are microperthite, microperthitic microcline, quartz, plagioclase, biotite, garnet and zircon. It is difficult to decide whether this is an intrusive granite or an altered sediment, but the former is the more probable.

A mile west, up Mill brook, is the old Lee mine; its walls are a red granitic rock now strongly gneissoid. Much the same rock appears in the walls of the old Essex county ore bed in the northern slope of Bulwagga mountain, but all these last three have been colored in as Grenville. Again in the ridge, an eighth of a mile north of the east end of Crowfoot pond, granitic gneisses again appear, different from the run of the syenite series, but no special color has been given them.

Anorthosites

The anorthosites are believed to be the oldest of the eruptives. They certainly followed the sediments because of the included masses which will be later described. They preceded the Split Rock falls type because we find inclusions of them in the latter. They are believed to be older than the syenites, not from any positive evidence in the area under discussion but because they have been clearly shown to be such by H. P. Cushing in the Long Lake

quadrangle, where the writer has had the privilege of seeing the critical exposures.[1] The syenites are essentially the same kind of rock in both localities and in default of positive evidence which may appear at any time within the present area, this relationship is assumed.

The anorthosites were called by Professor Ebenezer Emmons in his extremely valuable Report on the Second District, "hypersthene" or "labradorite rock," but inasmuch as the hypersthene is very subordinate and as neither of these is a good rock name, the term first employed by Dr T. Sterry Hunt in Canada, is here preferred, as it is generally by geologists today.

The anorthosites vary from almost pure aggregates of plagioclase crystals through variations caused by increasing amounts of a pyroxenic component. The commonest of the pyroxenes are hypersthene and green augite, the latter on the whole being perhaps more abundant than the former. More or less titaniferous magnetite also appears. The rocks are normally very coarsely crystalline. In the central portion of the great masses, feldspar crystals, apparently not connected with pegmatite veins may sometimes be seen as large as a man's hand. Crystals two or three inches across are not uncommon. Well crystallized and uncrushed specimens are rare. The entire area has been subjected to such severe pressure and granulation that the outer borders of the crystals are almost always crushed to a finely granular and whitish mass. Within this rim the bluish nuclei of the plagioclases remain. When shearing and dragging has been added the nuclei yield augen-gneisses of the most typical and instructive kinds. The crushing may go so far as to destroy all nuclei and leave a whitish or greenish pulp of secondary products. This is closely akin to saussurite. When weathering is added the rocks are often extremely white on exposed surfaces, appearing almost as if whitewashed.

The plagioclase crystals sometimes assume elongated forms and suggest a coarse diabasic texture when there is sufficient of the dark silicates to bring this out. Rarely the plagioclase exhibits the characteristic irridescence of certain labradorites. It has not been noted in this quadrangle but in the Mt Marcy group it is not uncommon in the beds of brooks, where either from pebbles, by chance properly cut, or from the smooth bed rock the irridescence flashes out to the observer.

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[1] Cushing, H. P. Geology of the Long Lake Quadrangle. N. Y. State Mus. Bul. 115. 1907. p. 481.

The variety of the plagioclase is best shown by the chemical analysis later cited but it can also be determined in an approximate way by means of the extinction angles. Measurements of specific gravity would also be significant but they have not been used as the above tests were esteemed sufficient. The plagioclase lies most often just beyond the labradorite ranges of Ab_1 An_1 to Ab_1 An_2[1], yet short of the bytownite of Ab_1 An_3.

In the more basic varieties we find the upper limits of the bytownite series also represented.

Under the microscope and when the original texture of the rock has not been crushed and destroyed, the thin sections show between crossed nicols the characteristic twinning of the plagioclases in a remarkable degree of perfection. For purposes of instruction few rocks are so well adapted for illustrating these phenomena. At times the bands cross the crystals with mathematical regularity and perfection; again they interpenetrate and pinch out like interlocked fingers and hands. Even with low powers the plagioclase reveals the very minute dusty inclusions, which in somewhat sparse arrangement are distributed throughout the clear mineral. With high powers the dust is seen to be in largest part an opaque to dark brown mineral, in prismatic or tabular form according to the orientation and doubtless ilmenite. Rarer pale green fragments are probably diopside and spinel. The inclusions may be strung out in lines parallel to the main twinning. They are never abundant enough to affect the transparency of the slide in any appreciable degree and in this respect they are inferior in amount to those in the basic gabbros to be later described.

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[1] In the algebraic designation of the plagioclases, they are considered combinations of the albite molecule, Na_2O, Al_2O_3, $6SiO_2$, written Ab and the anorthite CaO, Al_2O_3, $2SiO_2$, written An. The following varieties are recognized by students of rocks.

Albite	Ab_1 An_0 through Ab_8 An_1
Oligoclase	Ab_6 An_1 through Ab_2 An_1
Andesine	Ab_3 An_2 through Ab_4 An_3
Labradorite	Ab_1 An_1 through Ab_1 An_2
Bytownite	Ab_1 An_3 through Ab_1 An_6
Anorthite	Ab_1 An_8 through Ab_0 An_1

Although the above is the assignment of species generally given in the textbooks it is not a good one, since there are uncovered gaps between each group. Ab_1 An_7 for example is not provided for. It should read Albite Ab_1 An_0 to Ab_8 An_1; Oligoclase Ab_8 An_1 to Ab_2 An_1; Andesine Ab_2 An_1 to Ab_4 An_3; Labradorite Ab_4 An_3 to Ab_1 An_2; Bytownite Ab_1 An_2 to Ab_1 An_6: Anorthite Ab_1 An_6 to Ab_0 An_1.

Many years ago the late George W. Hawes[1] noticed in slides of these rocks some feldspars which failed to afford the twinning striations yet which he suspected of being plagioclase. Analytical tests demonstrated that they were. The same untwinned character may reappear so that the observer must be on his guard, but it is also true that a chance section parallel to the twinning plane would also be without the striations.

The analyses demonstrate the presence of potash quite without exception. The extreme rarity of biotite in the localities where the specimens taken for analysis were collected make it practically certain that the potash is in the orthoclase molecule and that this feldspar is in the rocks up to 5 per cent or over. It would also yield untwinned feldspar, which could only be distinguished from plagioclase by refined optical tests.

The analyses prove that quartz is at times present in amounts even reaching 8 per cent. The observer would need to exercise care not to overlook this mineral, yet despite the rather large percentage indicated by the recasting of the analyses it is rare to detect it in the slides. It is possible that it may be separated in part during the process of saussuritization, and be so finely divided in this indefinite, cloudy mass as to escape notice.

Microscopic study has shown that the commonest and most widely distributed pyroxenic component is a pale green variety, no doubt near diopside if not actually this molecule. The relatively high percentage of lime in the analyses is sufficient to more than satisfy the anorthite molecule and still leave an excess for the pyroxene, while the relatively low magnesia and iron serve to keep the hypersthene molecule somewhat in the background. Hypersthene is, however, abundant and widely distributed and as soon as the percentages of magnesia and ferrous iron rise and the anorthosites develop larger percentages of the pyroxenic components, the hypersthene becomes prominent. In the more coarsely crystalline and pegmatitic phases the hypersthene assumes a coarseness of crystallization which combined with its easily recognized bronze luster, makes it catch the eye of the observer and convince him of its presence. In the typical anorthosites the pyroxenic components are smaller in size than the feldspars and are packed in between the latter. Actual contact between the two, and especially in the

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[1] Hawes, George W. On the Determination of Feldspar in thin sections of Rocks. U. S. Nat. Mus. Proc. 1882. 4:134–36.

crushed and sheared varieties is often prevented by the intermediate rims of garnet to which reference will be made later.

Just east of Elizabethtown village in Green hill and Raven hill as well as to the north in the Ausable quadrangle, the anorthosite has much reddish brown biotite instead of the exclusive pyroxenic mineral. The feldspar is also often reddish or brownish and as crushing is not pronounced the rock looks much more like a coarse mica-syenite or nephelite-syenite than like anorthosite. Yet microscopic investigation has invariably shown the feldspar to be plagioclase of the normal type.

The anorthosites are believed to grow more basic toward the borders. The pyroxenic component becomes more and more pronounced and in the end instead of forming 5 to 15 per cent of the rock, it may be 25 or over. In this respect the writer's observations are in accord with those already published by H. P. Cushing for the northwestern areas. The rock then shades into a very coarse gabbro, but the plagioclase is always the most prominent member and in the field in order to maintain the distinction between the anorthosites and the basic gabbros these varieties have been called pyroxenic anorthosites. The sole difference is the increase in the bisilicates.

Another mineral of almost universal occurrence in the anorthosites is garnet. Over much of the area it is rare to find the labradorite in contact with the titaniferous magnetite or pyroxene. Almost always there will be an intermediate rim of garnet which surrounds the pyroxene or iron ore like a little crown of highly refracting pink grains. Even in the hand specimens the rock is a very beautiful one but under the microscope where the garnets stand out in relief the effect is even more impressive. The garnet rims are not limited to the anorthosites but are found in the rocks of the next type and also in the basic gabbros under which they will be again referred to as the garnets are accompanied by other minerals. The rims rarely appear in the syenites.

Larger masses of deep red garnets are also sometimes met, looking like knots in a board. They have probably recrystallized from pyroxenic material once present in the anorthosite.

Chemical composition. No special analyses of the typical anorthosite from this area have been prepared. The rock seems so simple in its mineralogy as scarcely to require them. Such analyses, however, as have been made of similar types either in neighboring or remoter localities, even including Norway, are given below, together with the percentage composition in actual minerals

when the analyses are recast according to the methods now much in vogue and extremely useful.[1]

	1	2	3	4	5
SiO_2	59.55	54.62	54.47	53.43	51.62
Al_2O_3	25.62	26.5	26.45	28.01	24.45
Fe_2O_3	.75	.75	1.3	.75	1.65
FeO	......	.56	.67	......	5.3
MgO	tr.	.74	.69	.63	1.21
CaO	7.73	9.88	10.8	11.24	9.97
Na_2O	5.09	4.5	4.37	4.85	3.49
K_2O	.96	1.23	.92	.96	1.27
H_2O	.45	.91	.53	tr.	.72
P_2O_5	......	......	......	......	.01
MnO	......	......	......	......	.1
	100.15	99.69	100.20	99.87	99.79
Sp. gr.	2.66	2.7	2.72	2.67	2.798

1 Chateau Richer, Quebec. T. S. Hunt. Geol. Sur. Can. 1863.

2 Keene valley. A. R. Leeds. N. Y. State Mus. 30th An. Rep't. 1878. p. 92.

3 Summit of Mt Marcy. A. R. Leeds. N. Y. State Mus. 30th An. Rep't. 1878. p. 92.

4 Nain. Labrador. A. Wichmann. Zeitschr. d.d. Geol. Gesellsch. 1884. 36:491.

5 Carnes Quarry, Altona, Clinton co. E. W. Morley for H. P. Cushing. N. Y. State Geol. 19th An. Rep't. 1901. p. 58.

[1] The recasting of analyses was first practised by W. C. Brögger of Christiania about 1890, and has given a new significance to the chemistry and mineralogy of rocks. A simple exposition of the methods employed will be found in Kemp's *Handbook of Rocks,* the calculations being pursued only so far as they give results representing actual rock-making minerals. A more elaborate method has been developed by Messrs Cross, Iddings, Pirsson and Washington in *The Quantitative Classification of the Igneous Rocks,* but in its application the authors are forced because of the complicated mineralogy of many rocks to assume some minerals or molecules which, so far as we know, are not in the rocks under discussion. While the variation from the actual mineralogical composition is oftentimes not necessarily great, yet hypothetical conditions are unavoidably assumed. In the recasting here employed, only those mineralogical molecules are used which we have reason to believe are in the rock. While the results are not mathematically accurate and while in some cases an excess or a deficit of a component has been encountered, yet the results must be very near the truth. They have their value in that they focus attention upon the percentages of the several minerals rather than, as in chemical analyses, upon uncombined oxids.

	1	2	3	4	5
Quartz	8.64	1.56	1.62	2.4	5
Orthoclase	5.56	7.23	5.004	5.56	7.5
Plagioclase	81.322	82.2	84.186	91.57	61.7
Magnetite	.464	.93	1.856	.464	2.4
Kaolin	2.58	3.87	2.58	......	......
Excess Al_2O_3.........	1.122	......	......	......	......
Water	.09	.11	.15	......	......
Garnet	......	......	......	......	11.75
Diopside. Hypersth...	......	4.3	4.616	3.224	11.
Light colored min....	99.234	93.97	93.39	97.14	74.2
Dark colored min....	.464	5.23	6.572	3.688	25.15
Plagioclase	Ab_1 $An_{1.7}$	Ab_1 $An_{2.4}$	Ab_1 An_3	Ab_1 $An_{2.1}$	Ab_1 $An_{2.4}$

1 Chateau Richer, Quebec. T. S. Hunt. Geol. Sur. Can. 1863.

2 Keene valley. A. R. Leeds. N. Y. State Mus. 30th An. Rep't. 1878. p. 92.

3 Summit of Mt Marcy. A. R. Leeds. N. Y. State Mus. 30th An. Rep't. 1878. p. 92.

4 Nain. Labrador. A. Wichmann. Zeitschr. d.d. Geol. Gesellsch. 1884. 36:491.

5 Carnes Quarry, Altona, Clinton co. E. W. Morley for H. P. Cushing. N. Y. State Geol. 19th An. Rep't. 1901. p. 58.

In the quantitative system the first four analyses belong in class I, Persalane, order 5, Perfelic, Canadare. No. 1 is in rang 3, Alkalicalic, subrang 5 Persodic. Nos. 2, 3 and 4 are under rang 4, Docalcic Labradorase, subrang 3, Persodic, Labradorose. No. 5 belongs in class II, Dosalane, order 5, Perfelic Germanare, rang 4, Docalcic, Hessase, subrang 3, Persodic, Hessose.

Of the five analyses the first four are characteristic anorthosites but the last marks a transition to the gabbros proper. The larger percentages of ferrous iron and magnesia are the indication of this and are of course the result of increasing amounts of the pyroxenic component.

In recasting the analyses some important assumptions were necessary, which do not materially change the results. Thus when water was not determined in parts above and below 110 C. it was arbitrarily divided into combined and absorbed. Fe_2O_3, which in nos. 1 and 4 includes some FeO, was broken up so as to give magnetite. In no. 1 after the best possible combination of oxids, 1.122 Al_2O_3 remained, and in no. 3, the SiO_2 failed to satisfy its natural associates by 2.40. There were probably some slight errors in determinations, for there seems no escape from the mineralogical compositions used. In no. 5 the most basic one and obviously well over toward the gabbros, the recast values are taken from results given by Professor Cushing and involve no kaolin.

The results show that quartz may be expected in the moderately silicious ones although it may not be sufficiently abundant to catch the eye of the observer. The orthoclase molecule is also seldom visible in the slides. The plagioclase lies near the labradorite series but when the anorthite molecule passes the 2. ratio it approximates bytownite. The overwhelming percentage of the feldspar is apparent. The anorthosites are rich in the light colored minerals beyond the vast majority of eruptive rocks. To what extent the ferromagnesian molecules are to be assigned to diopside and hypersthene is not apparent. Microscopic study proves both to be present but their total is small at best.

We have thus to deal with a great eruptive magma, containing little else than silica, alumina, lime and soda. Although the first to appear in a series it is probably a differentiation product from an earlier original richer in iron and magnesia. The later residual outbreaks profited by these accumulated bases which were left behind.

Inclusions. In the bare ledges along Coughlin and Stevens brooks which flow eastward down the eastern buttress of Giant mountain several cases of included fragments of older rocks, undoubtedly belonging to the Grenville series have been discovered. Figure 4 illustrates the shape and size of one. They have uniformly a garnetiferous border marking their boundaries against

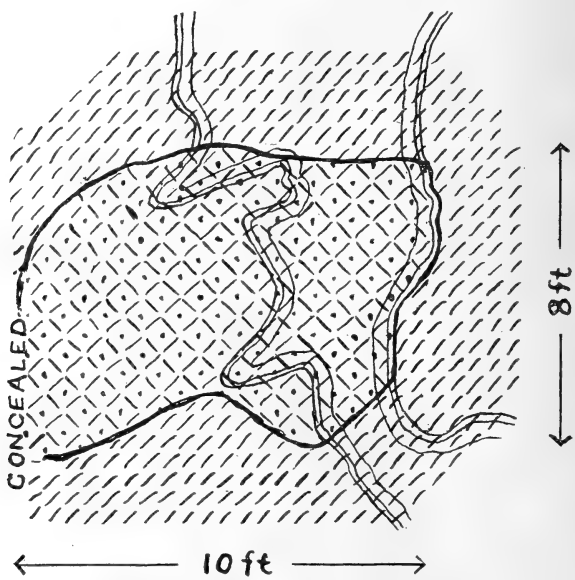

Fig. 4 Fragment of quartzite, included in anorthosite. Bed of Coughlin brook, about 1 mile west of highway.

the anorthosite. They themselves are chiefly a mixture of quartz and diopside. Each of these minerals makes up about half of the slide, the only additional component being a small grain of apatite. The crystals range up to 2 millimeters in diameter. The diopside is of irregular outline, of a pale green color, with slight pleochroism to yellow. The quartz is strained around the edges, and in one slide is cloudy at the center of the crystals because of innumerable, minute acicular inclusions, probably rutile, and oriented in every direction. Presumably the original rock was a quartzose and somewhat calcareous clastic, which on recrystallization has afforded the minerals described. The edges of the inclusion, being melted into the more calcareous anorthosite yielded the garnet rims.

Rocks of this composition are well recognized members of the Grenville, and have been described by H. P. Cushing under the name of quartz-diopside rock in Museum Bulletin 115, pages 504–8. To the unaided eye they resemble coarsely crystalline quartzites and as such were collected in the field. The best explanation of these curious masses of rock is the one which refers them to original Grenville strata pierced by the intrusive anorthosite, which tore off and included fragments and did not entirely absorb them.

Border facies of anorthosite. Around the borders of the main great intrusion, the anorthosites in this as in neighboring areas take on more dark silicates and lose also the distinctive bluish or greenish color of the feldspar, which is quite characteristic of the central portions. Professor Cushing has observed the same feature in the Long Lake area,[1] and has given it a special color on his map.

Several years ago while in the field upon the Lake Placid quadrangle, this feature was noted in the rocks of Whiteface mountain and in the notes the rock was called the Whiteface type. A sample from the summit of this mountain was analyzed by George Steiger in the laboratory of the United States Geological Survey with the results given below. The feldspar of the rock is white and shows evidence of crushing and granulation. The dark silicates are much more abundant than in the typical anorthosite and besides the pyroxenic minerals, diopside and hypersthene, hornblende is frequent.

This same type of rock has been noted northeast and east of New Russia and it forms a small prong of Oak hill.

The Whiteface type has a medium percentage of silica as the anorthositic rocks run. There are other varieties with somewhat

[1] N. Y. State Mus. Bul. 115, p. 473.

more silica and yet with nearly 15 per cent of dark silicates and still others with less and larger percentages of the ferromagnesian minerals. In the first two analyses given below, no. 1 and no. 3 are probably not separate intrusions from the main anorthosite mass but merely more ferromagnesian phases. No. 2, the Whiteface type, is interpreted in the same way. It is not easy in these cases to decide whether we are dealing with a separate intrusive mass of mineralogy closely related, or not. Irruptive contacts against the anorthosites have not been discovered and the location of these varieties around the borders of the main mass leads to the interpretation of them as rim facies.

There are, however, at least two cases in which intrusive relations to the anorthosites can be demonstrated in more basic rocks but ones of different type from the distinctively basic gabbros. In the one case included fragments of anorthosite have been discovered in the mass of gabbro; in the other irruptive contacts are displayed. In both instances gneissoid structures have been subsequently induced by pressure.

	1 Pyroxenic anorthosite, Elizabethtown	2 Pyroxenic anorthosite, summit of Mt Whiteface	3 Pyroxenic anorthosite, Giant trail, Keene valley
SiO_2	56.94	53.18	52.37
Al_2O_3	20.82	23.25	24.68
Fe_2O_3	.83	1.53	1.24
FeO	3.02	1.82	3.49
MgO	2.36	2.60	2.00
CaO	9.41	11.18	10.57
Na_2O	3.36	3.97	4.02
K_2O	1.58	.86	.86
H_2O+	.59	.98	.90
H_2O-	.21	.15	....
CO_2	.45	.34	....
TiO_2	.44	.45	....
S	....	tr	....
P_2O_5	.07	.09	....
MnO	.11	.11	....
BaO	.05	....	....
	100.24	100.51	100.13
Quartz	7.20		Deficit .90
Orthoclase	9.45	5.00	5.00
Plagioclase	61.10	69.12	80.52
	$Ab_1An_{2.2}$	Ab_1An_2	$Ab_1An_{2.64}$
Pyroxenes	14.84	15.36	12.86
Apatite	....	.21	....

	1 Pyroxenic anorthosite, Elizabethtown	2 Pyroxenic anorthosite, summit of Mt Whiteface	3 Pyroxenic anorthosite, Giant trail, Keene valley
Magnetite	1.16	2.09	1.62
Titanite	1.00	.99	....
Calcite	1.00	.80	....
Kaolin	4.39	6.97	....
Total	100.14	100.54	100.90
Light colored minerals	83.14	81.89	85.52
Dark colored minerals	17.00	18.65	14.48

No. 1. Pyroxenic anorthosite from the Woolen Mill, 1 mile west of Elizabethtown. Analysis by W. F. Hillebrand in the laboratories of the United States Geological Survey.

No. 2. Pyroxenic anorthosite summit of Mt Whiteface. Lake Placid quadrangle. Analysis by George Steiger in the laboratories of the United States Geological Survey.

No. 3. Pyroxenic anorthosite, High fall, Giant trail, Mt Marcy quadrangle. Analysis by C. A. Jouet. Department of Chemistry, Columbia University.

The analyses are arranged according to the decreasing percentages of silica. As the recalculation shows, lower silica does not necessarily imply higher percentages of the pyroxenic constituents since no. 3, the lowest in silica, has the highest percentage of feldspar and the lowest of the dark mineral. Its feldspar is, however, the most basic of all, being within the bytownite ranges.

In the quantitative system all three fall within class II, Dosalane, order 4, Germanase, rang 4, Docalcic, Hessase, subrang 3, Persodic Hessose.

Intermediate gabbros demonstrably later than the anorthosites

Special interest attaches to the two members of this variety which have afforded evidence of the relative periods of intrusion. In the case first cited, the succession has been shown by included masses; in the second instance, the irruptive contact can be followed for over a hundred yards in the rocky bed of a brook, fortunately in a very accessible locality. The two cases will be described under locality names as the Split Rock falls, and the Woolen Mill.

Split Rock falls locality. In the valley of the Boquet river and south of New Russia there is an intrusive mass which covers 5 or 6 square miles and which is distinct from the anorthosites of the

mountains to the westward. It outcrops in typical development at Split Rock falls, where in the cascades of the Boquet it is well

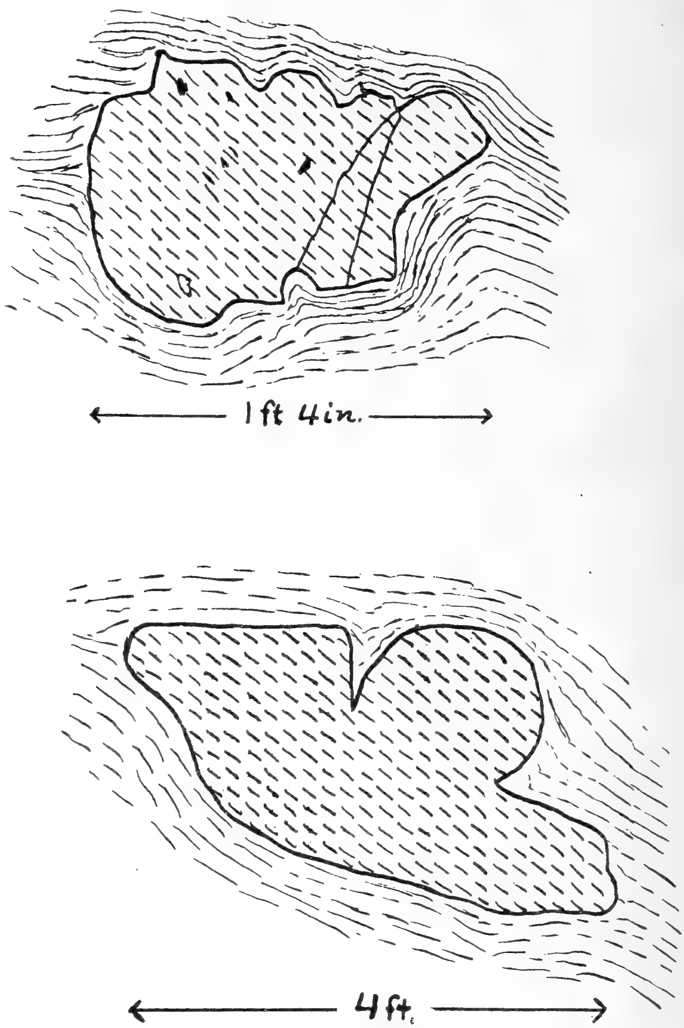

Fig. 5 Two inclusions of anorthosite in Split Rock Falls type, at Split Rock falls

exposed. The rock is suggestive of the anorthosites in that blue labradorite is the chief feldspar present, but the dark silicates are more abundant and when crushed and sheared the rock yields a decidedly foliated gneiss. It then becomes a hard dense rock, extremely tough. Nevertheless, large phenocrysts of labradorite are

not uncommon and the gneiss often exhibits the "augen" produced from them.

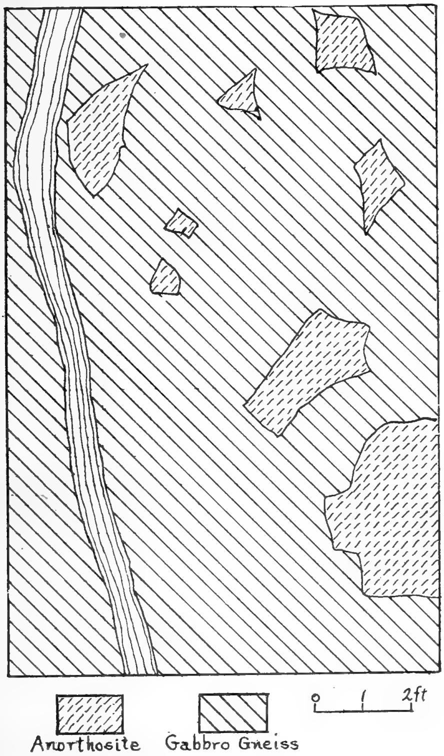

Fig. 6 Inclusions of anorthosite in gabbro of the Split Rock Falls type. Ledges on Slide brook

This intrusive is known to be later than the anorthosites because in the bare ledges along the cascades at Split Rock falls, inclusions of anorthosite are found in it. Each is surrounded by a garnet rim which appears to represent magmatic or corrosion phenomena.

Woolen Mill locality. On the south side of the Branch a mile to the west of Elizabethtown and near the mill there is a very interesting rock which exhibits an irruptive contact with the anorthosite and extends both westward and southward. It is dark, gneissoid and of moderate coarseness of grain. It resembles a rather basic member of the syenite series but has occasional blue labradorite phenocrysts which ally it with the anorthosites. Under the microscope and in slides from specimens without the labradorite phenocrysts, the minerals are, rather deep green pyroxene, sometimes showing faint pleochroism to yellow, plagioclase, ortho-

clase, quartz, garnet, magnetite and pyrrhotite as the chief components. Apatite of course appears in occasional crystals, and biotite is moderately frequent at times and again rare. The same is true of hornblende. The individuals, except for the rare phenocrysts rarely reach 1 millimeter in diameter, ranging from .25 to .5 millimeter. They are irregular in shape so that the rock is finely granitoid in texture. It is rather dark gray in color and is strongly contrasted with the anorthosite against which it lies. The rock has undoubtedly been granulated to an appreciable degree by pressure and crushing. The edges of the components frequently show strains under crossed nicols.

Two analyses have been prepared of the gabbro, one from a locality just below the dam at the mill, no. 2; and the other, no. 3, of a more acidic phase farther up stream. No. 2 is by Dr W. F. Hillebrand and was made in the laboratories of the United States Geological Survey; no. 3 is by Dr C. A. Jouet in the laboratories of Columbia University. No. 1 is the anorthosite and is repeated from p. 36.

	1	2	3
SiO_2	56.94	47.16	50.54
Al_2O_3	20.82	14.45	21.28
Fe_2O_3	.83	1.61	3.43
FeO	3.02	13.81	8.73
MgO	2.36	5.24	2.08
CaO	9.41	8.13	8.72
Na_2O	3.36	3.09	2.95
K_2O	1.58	1.20	1.63
H_2O+	.59	.48	.35
H_2O-	.21	.12	.06
CO_2	.45	.35	present
TiO_2	.44	3.37	....
P_2O_5	.07	.57	....
MnO	.11	.24	.40
BaO	.05	....	....
S	....	.14	.64
NiO.CoO	....	.02	....
	100.24	99.98	100.81

	1	2	3
Quartz	7.20	....	3.60
Or	9.45	7.23	7.23
Ab	28.30	26.20	25.15
An	32.80	18.07	27.80
Kaolin	4.39	3.43	2.58
Calcite	1.00	.80	....

	1	2	3	
$CaO.SiO_2$	4.06	6.96	2.90	Augite and Hypersthene
$MgO.SiO_2$	5.90	5.40	4.10	
$FeO.SiO_2$	4.88	7.13	5.28	
$MnO.SiO_2$	....	.40	.66	
$MgO.Al_2O_3.SiO_2$	....	....	1.41	
$FeO.Al_2O_3.SiO_2$	....	....	1.64	
$K_2O.Al_2O_3.2SiO_2$	....	....	1.26	Biotite
$2MgO.SiO_2$	....	....	.56	
$2FeO.SiO_2$	....	....	.82	
$3CaO.Al_2O_3.3SiO_2$	....	....	4.50	Garnet
$3FeO.Al_2O_3.3SiO_2$	....	....	4.98	
$2MgO.SiO_2$	....	5.46	....	
$2FeO.SiO_2$	....	8.36	....	
Magnetite	1.16	2.32	4.87	
Ilmenite	....	6.23	....	
Apatite	....	1.34	....	
Pyrrhotite	....	.35	1.65	
H_2O—	....	.12	.06	
Ilmenite	1.00	....	....	
Total	100.14	99.80	101.05	
	$Ab_1An_{2.2}$	$Ab_1An_{1.3}$	Ab_1An_2	
Light colored minerals	83.14	55.73	66.36	
Dark colored minerals	17.00	43.95	34.63	

In the quantitative system, nos. 1 and 3 are both in class II, Dosalane, order 5, Germanase, rang 4, Docalcic, Hessose and subrang 3, Persodic, Hessose. No. 2 comes under class III, Salfemane, order 5, Gallase, rang 4, Docalcic, Auvergnase, subrang 3, Auvergnose.

The recasting of no. 1 presents no difficulties; the calculated results correspond closely with the observed minerals, with the possible reservation that the quartz does not impress one as being so abundant in the slide. No. 2 is also not a difficult analysis to recast and still deal only with observed minerals. The only surprising feature is that the relatively small percentage of alumina restricts the possibilities of the anorthite molecule and leads to a variety of plagioclase, $Ab_1An_{1.3}$, unexpectedly acidic for so basic a rock. It seems peculiar to have in the most basic of the three analyses the most acidic feldspar. In no. 3, the slides reveal a complicated mineralogy, since we have both biotite and garnet to deal with, and assumptions are unavoidable in the distribution of certain oxids. Thus there is slight opportunity for error in the pyrrhotite and albite. As regards the others, we are in doubt as to the division of the K_2O between the orthoclase and biotite, although it is evident from the slides that the greater part belongs with the

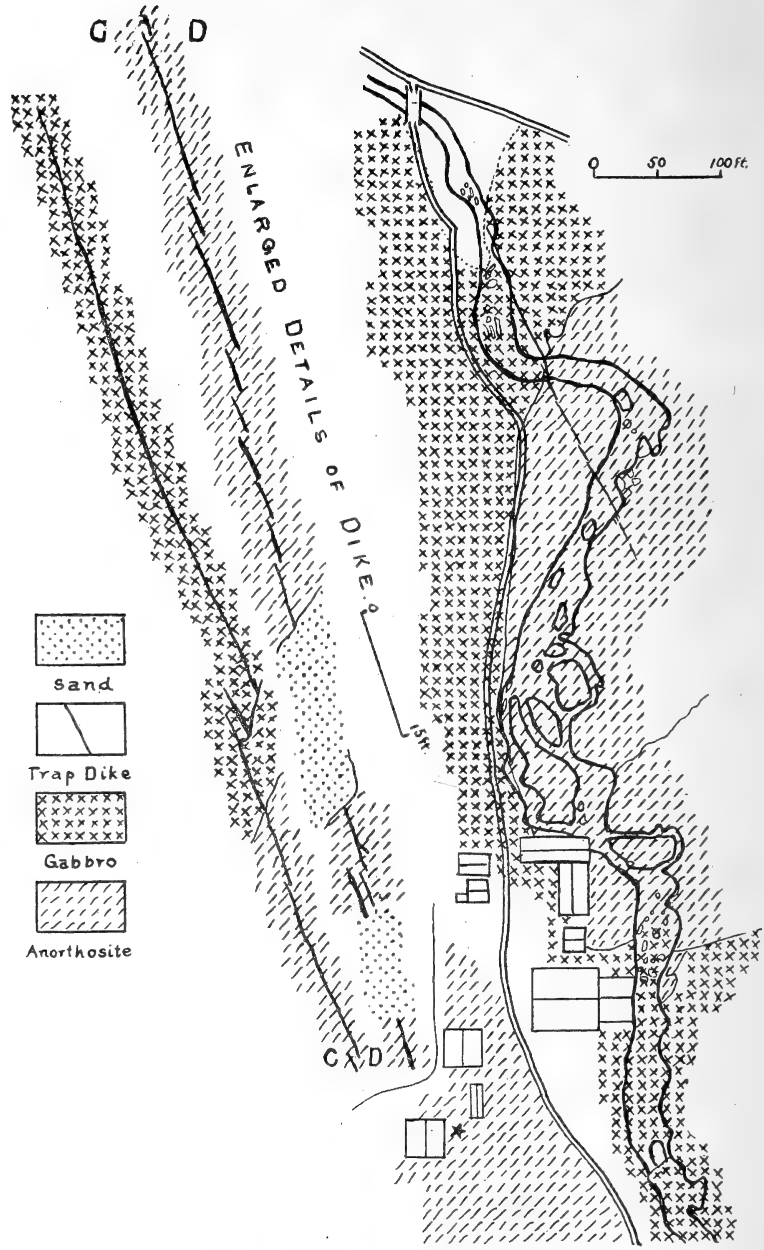

Fig. 7 Map showing irruptive contacts of the Woolen Mill type of gabbro and anorthosite. Both are cut by a basaltic dike. The "Branch" 1 mile west of Elizabethtown

former which is more abundant. There may be a little H_2O in the biotite, but it has all been assigned to kaolin. The division of the CaO among anorthite, pyroxene, garnet and possible hornblende is purely an estimate. In the recasting about two thirds the molecules were assigned to the anorthite, while the remainder were allotted to garnet and pyroxene (including hornblende). The FeO and MgO had to be divided between biotite (a relatively small portion) and pyroxene (hornblende). Some FeO was also used for garnet. There is more than enough Al_2O_3 for the feldspar, biotite and garnet, so that a small residue was placed in the pyroxene as is doubtess justifiable. All the Fe_2O_3 was used for magnetite, as this assumption did not yield any more than is obviously present in the slides. The composition of the garnet was necessarily assumed to involve both the grossularite and the almandite molecules. There is probably a little TiO_2 in the rock but if so it is presumably in the magnetite for no titanite worth mention was observed. After all these assumptions, suggested or checked by estimates of the relative abundance of the minerals as seen under the microscope, the above result was reached. It is difficult to believe that a molten magma of only 50.54 per cent silica would crystallize directly from fusion so as to yield this excess of silica forming 3.60 of quartz. If we recast without using the garnet molecule and with the allotment as usual of all the alumina remaining above the orthoclase, albite and kaolin, to the anorthite, only a tenth as much or about .30 remain uncombined. The natural inference follows that the garnet has resulted from metamorphic reactions between the pyroxene and anorthite, in which the lime and alumina of the latter were utilized and the silica left free.

The Woolen Mill locality is not the only one for this variety of rock, or at least for one that to the eye appears to be the same. Blueberry mountain along the southern border shows the same general aspect with occasional large blue crystals of labradorite.

New Pond locality of a peculiar gabbro. Along the road leading into New pond and an eighth of a mile before it terminated at the pond itself, a ledge of a very peculiar eruptive was found, which differs from all others mentioned. It consists of sharply angular crystals of plagioclase, rectangular in cross section, imbedded in a dark green matrix of what proves under the microscope to be granules of augite. This rock has been seen in boulders within a mile or so of the locality mentioned and may be more widely distributed. It has also been seen in the Mt Marcy quadrangle along the highway about a half mile south of Beede's. The

affinities of the rock are rather with the anorthosites than with the basic gabbros.

The relations of this rock to the other eruptives and the sedimentaries have been nowhere shown as the exposures were so limited that no conclusion could be drawn. The rock is one admirably adapted to give pronounced hornblendic gneiss under shearing and stretching and it may have been the original of some of the puzzling gneisses occasionally seen in the region. Under metamorphism the augite would pass into hornblende and the relations of it to the feldspar are exactly those which would yield interleaved lenses when crushed and drawn out.

Syenite series

The syenitic series has been one of comparatively late recognition in Adirondack geology. The rocks were first identified as eruptives on the western side of the Archean area by C. H. Smyth.[1] Soon thereafter the significant exposures found by H. P. Cushing in the railway cut near Loon Lake station on the northern side demonstrated their intrusive relations with the Grenville.[2]

The writer has also noted briefly the occurrence of green gneisses in Ticonderoga which were suspected of being eruptive,[3] but it was only after an instructive trip with Professor Cushing to the Loon Lake occurrence that the identity of these rocks was demonstrated. At times they look much like anorthosites especially in their crushed and gneissoid phases, and again they have been classed with the supposed ancient gneisses. The series embraces variations from the typical composition of syenite but the minerals with minor additions are the same and there are intermediate phases. As components of the Adirondack area the syenites do not yield in importance, even to the anorthosites, and their recognition has served to remove a vast amount of hitherto puzzling rocks from the noncommittal designation "gneiss."

In typical and least altered form the syenite is a dark green massive rock, of moderate coarseness of grain. Its components

1 Smyth, C. H. jr. Crystalline Limestones and Associated Rocks of the Northwestern Adirondack Region. Geol. Soc. Am. Bul. 6. 1895. p. 271–83. Report on the Crystalline Rocks of the Western Adirondack Region. N. Y. State Geol. 17th An. Rep't, p. 472.

2 Augite-syenite Gneiss near Loon Lake, N. Y. Geol. Soc. Am. Bul. 10. 1899. p. 177–92. Geology of the Northern Adirondack Region. N. Y. State Mus. Bul. 95. 1905. p. 312; Bul. 115. 1907. p. 512.

3 Preliminary Report on the Geology of Essex County. N. Y. State Geol. An. Rep't for 1893. 1894. p. 452.

never reach the great sizes of the labradorites in the coarse anorthosites, but range not far from the dimensions of those of the ordinary granites. The green feldspar is the chief component but with it are dark silicates sometimes in relatively large amount. Quartz is not lacking entirely but can not often be seen by the unaided eye. The analyses which have been prepared especially in connection with Professor Cushing's work show percentages in silica which usually range between 60 and 65 or under those of typical granite but there are close relatives both above and below these values. The potash and soda are generally present in nearly equal amounts.

The following analyses have been selected to illustrate the run of composition. None are based on samples taken in the area covered by this bulletin, but they represent all sides of the Adirondack region, and undoubtedly could be duplicated in the former. Later analyses of a series from Mineville will be given, which depart in both directions from the compositions here cited. The Ticonderoga case, no. 5, is the nearest to the Elizabethtown and Port Henry quadrangles. The sample was taken near the railway crossing of the Lake George outlet and is about 15 miles from Port Henry. As soon as one examines these analyses, they are seen to be obviously closely akin. The low magnesia and the nearly balanced alkalies are striking.

ANALYSES OF SYENITES.

	1	2	3	4	5	6	7
SiO_2	68.50	66.72	64.47	63.45	62.41	61.01	59.70
Al_2O_3	14.69	16.15	10.51	18.38	18.75	15.36	19.52
Fe_2O_3	1.34	1.23	1.11	1.09	2.49	10.75	1.16
FeO	3.25	2.19	7.37	2.69	4.91		5.65
MgO	.26	.73	5.21	.35	.61	.78	.78
CaO	2.20	2.30	3.10	3.06	3.17	4.05	3.36

1 Quartz-augite syenite. Altamont, Franklin co. Analyzed by E. W Morley for H. P. Cushing. N. Y. State Mus. Bul. 115. 1907. p. 514.

2 Augite-syenite. Little Falls, Herkimer co. *Idem.*

3 Syenite, gneissoid. Whitehall, N. Y. Analysis by W. F. Hillebrand

4 Augite-syenite. Loon Lake, Franklin co. Analyzed by E. W. Morley for H. P. Cushing, who considers the occurrence as typical. Geol. Soc. Am. Bul. 10. 1900. p. 177. Revised in N. Y. State Mus. Bul. 115. 1907. p. 514.

5 Augite-syenite. Ticonderoga, Essex co. Analysis by M. K. Adams.

6 Augite-syenite. Altamont, Franklin co. Analyzed by E. W. Morley for H. P. Cushing, as under no. 1.

7 Augite-syenite. Line of townships 22 and 23. Franklin co. Analyzed by E. W. Morley for H. P. Cushing, as under no. 1.

	1	2	3	4	5	6	7
Na_2O	3.50	4.36	2.21	5.06	3.09	3.68	5.31
K_2O	5.90	5.66	3.63	5.15	4.25	3.90	4.14
H_2O+	......	......	.75	......	......	......	......
H_2O-	......	......	.18	......	......	......	......
H_2O	.40	.77	......	.30	.41	.49	.52
TiO_2	......	......	......	.07	......	......	......
P_2O_5	.03	......	.25	......	......	......	......
MnO	.10	.07	......	tr	......	.08	.09
BaO	.05	......	......	.13	......	......	......
S	......	......	.12	......	......	......	......
CO_2	......	......	.58	......	......	......	......
	100.22	100.18	99.49	99.73	100.09	100.10	100.23

1 Quartz-augite syenite. Altamont, Franklin co. Analyzed by E. W. Morley for H. P. Cushing. N. Y. State Mus. Bul. 115. 1907. p. 514.

2 Augite-syenite. Little Falls, Herkimer co. *Idem.*

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5 Augite-syenite. Ticonderoga, Essex co. Analysis by M. K. Adams.

6 Augite-syenite. Altamont, Fronklin co. Analyzed by E. W. Morley for H. P. Cushing, as under no. 1.

7 Augite-syenite. Line of townships 22 and 23. Franklin co. Analyzed by E. W. Morley for H. P. Cushing, as under no. 1.

In the quantitative system, nos. 1 and 2 fall under class I Persalane; order 4 Brittannare; rang 2 Toscanase; subrang 3 Toscanose.

Nos. 3 and 5 belong in class II Dosalane; order 4 Austrare; rang 2 Dacase; subrang 3 Adamellose.

No. 4 is in class I Persalane; order 5 Canadare; rang 2 Pulaskase; subrang 3 Pulaskose.

No. 7 is in the same except the subrang 4 Laurvikose.

No. 6 is in Class II Dosalane; order 4 Austrare; rang 3 Tonalase; subrang 3 Harzose.

Under the microscope the chief feldspar is at once seen to be microperthitic orthoclase; that is, the orthoclase of the ordinary syenites is filled with flattened, parallel blades or spindles of albite. This microperthite is very characteristic and with the beautiful emerald-green pyroxene affords one of the distinguishing features of this group of rocks. Plagioclase is not entirely lacking, and especially in the specimens from Mineville is at times quite prominent. Quartz is variable. As will be shown later there are phases, apparently differentiation products of the syenite magma, in which

it is very abundant, and the rock becomes a granite, or of granitic composition. In these the quartz is very abundant. Again in the basic extremes, it fails, and in the true syenite phases, the most characteristic of the series, it is rare or absent.

The most prominent of the dark minerals is a beautiful and striking emerald-green pyroxene. It has the high extinction angles of augite, and sometimes a faint pleochroism to yellow. Experience gained in recasting analyses leads to the conclusion that the jadeite molecule, Na_2O, Al_2O_3, $4SiO_2$, is present in its composition, and may be largely responsible for the beautiful green color, so suggestive of aegirite. The pyroxene often changes to chlorite and when present in the bodies of magnetite associated with the syenites, it yields red oxid of iron and stains the ore red by filtering into the cracks in the neighboring minerals. It has the same effect on the syenitic rocks, especially those associated with the ore. Under the miscroscope the reddish tinge can be traced back to the chloritized pyroxene.

Hypersthene is occasional in the syenites, but scarcely so abundant as to require extended description. Hornblende, however, is very common. It is a deep brown variety and in the basic types may be more abundant than pyroxene. Biotite is known but is subordinate. The basic phases have it more abundantly than the acidic. It is deep brown in color, but not otherwise remarkable.

Among the accessories titanite is sometimes extremely abundant. To the unassisted eye it might be taken for garnet, and in the acidic phases, associated with the magnetites, it makes this impression, but the microscope, of course, reveals its identity. Apatite is at times noticeably abundant but presents no peculiarities worthy of special remark. Zircon favors the acidic extremes. Magnetite is in all varieties, even the most acidic, where, unless sharply observed, it might be mistaken for a dark silicate. Pyrrhotite is rarely to be detected.

In earlier experience it was believed that garnet was practically limited to the anorthosites and basic gabbros, but as the tendency of the syenites to develop basic phases has been appreciated and the dark hornblendic gneisses have seemed to be, in part at least, referable to them, garnet has been recognized as one of their minerals. While the reaction rims, which will be more fully described under the basic gabbros, are far more abundant in these latter rocks, yet some cases have been observed in which they were also apparent in the syenitic gneisses. Some dark, hornblendic gneisses have, in the later field work, shown such relationship as to

be referable to the basic syenites and not necessarily to the gabbros, as formerly believed. Field associations and preponderance of orthoclase as seen under the microscope must hereafter decide.

On weathering, the syenitic rocks are particularly prone to develop a rusty exterior although just why the contained iron is in a condition so sensitive to alteration, is not apparent. When one seeks for a fresh hand specimen from fallen blocks, it is often necessary to pound off several inches or the better part of a foot before the fresh green rock appears at the core. Where polished off smooth and hard by glaciation, the rock may also develop a very white coat or skin which, however, is easily chipped off so as to expose the fresh green beneath.

The relative proportions of the several minerals vary widely over extended areas. Toward the acidic extreme, quartz may become increasingly abundant, fully enough to carry the rocks over into the granites. Such varieties appear on Barton hill near Mineville and in association with the ores of the great mines. Yet the microperthitic character of the feldspar is pronounced and the same augite and hornblende are in evidence which we find in the typical specimens, so that one can not well avoid the conclusion that there is a fundamental relationship.

Very instructive evidence has been afforded by the numerous diamond drill cores which have been obtained in the explorations for magnetite at Mineville. The writer has examined most carefully thousands of feet of these, and finds on the whole the average syenite most frequently present, but with no evidence of being a separate intrusive mass. The most acidic variety will quite sharply replace it; and in the same way a very basic variety may come in and constitute the section for 50 or 100 feet or more. Yet while the transition is sharp there is no evidence of separate intrusive masses nor is one justified in inferring more than a differentiation of an eruptive mass into layers or portions of contrasted composition. As will be later shown in speaking specially of the ores, the great body of magnetite lies immediately beneath the most acidic phase. The ore contains appreciable amounts of the emerald-green pyroxene and is simply an extremely basic concentration of one of the normal minerals, the magnetite, accompanied by two others, the pyroxene and apatite. Beneath the ore, usually if not always, is found a basic phase of the syenite. All these relationships will be more fully discussed from the standpoint of the ore on subsequent pages, the object being at the moment to emphasize the variability of the rock mass.

In the Ausable quadrangle very rusty basic dikes of the syenite series have been found, intrusive even in older and larger masses of the same series of rocks. The basic syenitic types develop under metamorphism a crumbling variety of gneiss, which on exposures that have been quite thoroughly weathered may be rubbed to coarse sand between the fingers. Black grains of silicates and ores then separate from rusty green feldspar.

Within the area here described all varieties of syenites show the effects of crushing and the production of gneissoid foliation to a marked degree and no locality can be cited free from it. Along fault planes, where dynamic effects are pronounced, much secondary quartz has sometimes been infiltrated and on weathering the rock becomes a pronounced red, looking like a coarse, red granite.

This so called syenite series has an exact parallel in Norway, where in association with anorthosites, practically indistinguishable from the Adirondack occurrences, C. F. Kolderup has established the existence of others consisting of microperthite and augite. The latter Kolderup calls by the new name mangerite, based on a Norwegian locality, Manger. This duplication on opposite sides of the Atlantic is an extremely interesting coincidence.[1]

The following analyses have been prepared of the syenites within the area covered by the bulletin, three of the samples having been taken from drill cores at Mineville. They represent the several varieties as well as selections would admit. With them is also placed one of a marked granitic phase, no. 1, which, however, careful study of relationships fails to prove a separate intrusive mass.

	1	2	3	4
SiO_2	68.87	73.84	52.01	45.81
Al_2O_3	10.76	14.11	16.93	20.32
Fe_2O_3	3.52	.22	.14	.53
FeO	1.26	1.12	10.25	8.45
MgO	2.27	.83	2.50	6.45
CaO	2.59	.44	6.14	7.97
Na_2O	2.45	6.36	4.65	4.53

1 Granitic extreme of syenite series 1 mile west of Mineville. Analyzed by Charles Fulton.

2 Granitic extreme of syenite series; hanging wall of magnetite. Mineville. Analyzed by M. K. Adams.

3 Average syenite of rocks containing the Mineville magnetite. M. K. Adams.

4 Basic syenite of rocks containing the Mineville magnetite. M. K. Adams.

[1] Kolderup, C. F. Die Labradorfelsen des westlichen Norwegens. Bergen's Museum's Aarbog. 1903. p. 102.

	1	2	3	4
K_2O	7.88	2.38	2.54	1.58
H_2O+	....	.46	.45	.60
H_2O-	....	.11	.02	.03
CO_2	....	.16	none	none
TiO_2	.14	.46	3.00	2.34
ZrO	....	.09	none	none
P_2O_5	....	.06	1.24	.53
S	....	.07	.27	.22
MnO	....	.03	.21	.15
BaO	....	none	tr	.02
Cr_2O_3	....	none	none	none
	....	100.74	100.35	99.53
O-S	....	.03	.10	.09
Total	99.74	100.71	100.25	99.44

	1	2	3
Quartz	21.540	24.540	....
Orthoclase	36.696	13.344	14.456
Albite	20.960	53.448	39.300
Kaolin	....	3.096	3.096
Calcite	....	.200	....
Titanite	.198	1.188	7.128
Zircon	....	.182	....
$CaO.SiO_2$	5.336	....	5.336
$MgO.SiO_2$	3.800	2.100	.900
$MgO.Al_2O_3.SiO_2$	....	....	1.616
$FeO.SiO_2$	1.848	1.716	17.688
$MnO.SiO_2$	....	....	.393
$2(K_2O.Fe_2O_3.2SiO_2)$	6.732	....	....
$2MgO.SiO_2$	1.260	....	....
Magnetite	.928	.232	.232
$MgO.Al_2O_3$	....	....	6.390
Pyrrhotite	....	.120	.480
Apatite	....	....	3.016
P_2O_5	....	.060	....
CO_2 excess	....	.044	....
H_2O-	....	.110	....
MnO	....	.030	....
Total	99.298	100.410	100.031

1 Granitic extreme of syenite series 1 mile west of Mineville. Analyzed by Charles Fulton.

2 Granitic extreme of syenite series; hanging wall of magnetite. Mineville. Analyzed by M. K. Adams.

3 Average syenite of rocks containing the Mineville magnetite. M. K. Adams.

4 Basic syenite of rocks containing the Mineville magnetite. M. K. Adams.

Endeavors to recast these analyses according to the mineralogy exhibited by the thin sections have not been very satisfactory.

No. 1 has involved several assumptions. The soda was first all assigned to albite. The remaining alumina was used for orthoclase, there being none for anorthite. The residue of potash, with the necessary ferric iron, was used for biotite, affording a variety abnormally high in the alkali but making very little difference in the gross result. Everything else was assigned to hornblende, except for the little magnetite and titanite. The slides reveal quartz, microperthite, biotite, hornblende, magnetite and zircon.

No. 2 presents no difficulties. The great preponderance of the light colored minerals is striking, since about 95 per cent consist of these. The remainder is chiefly augite although this mineral is a very obscure component to the eye. The richness in the albite molecule is striking. While this mineral is chiefly observed in microperthite, it can not obviously be altogether in this form, since 13 per cent orthoclase could hardly contain 53 per cent albite. While this rock is believed to be an acidic differentiation product from the syenitic magma, it is only fair to state that in one respect the analysis is similar to the usual run of slates and argillaceous sandstones, in that with high silica the magnesia exceeds the lime. The opposite relation usually holds for the eruptive rocks. Yet the amounts are small and other considerations lead to the interpretation as an igneous variety. The presence of zircon in the acid member and its failure in the basic is an interesting corroboration of our ordinary conceptions of the home of this mineral.

When the recasting of nos. 2, 3 and 4 are undertaken, difficulties arise in providing so much soda with sufficient silica to satisfy the albite molecule, at its ratio of one soda to six silica and yet have sufficient silica left to form unisilicates which take up the other bases. One can not but infer that the emerald-green pyroxene itself carries soda, but it can not be in the form of the acmite molecule, $Na_2O.Fe_2O_34SiO_2$ since we have so little Fe_2O_3, while magnetite is a certain component of the rock. The alumina is also in excess, and can only be provided for by the spinel molecule. Yet no spinel has been detected in the slides. Any form of the olivine molecule, and any corundum which we would use according to the methods of the "Quantitative System of Classification of Igneous Rocks" are also not to be observed in the slides. Nephelite can also not be detected in the slides although with basic rocks such as these, the rather high percentage of soda would seem to call for it.

The chemical analyses also throw some light on the question of their igneous or sedimentary nature. It will be observed that all the rocks are rich in soda, even the most basic. Were they recrystallized sediments, they must have been derived from shales, or in the most acidic cases, shaly sandstones, since no other sediments will give anything approximating these compositions. Yet in the process of disintegration of feldspathic rocks and deposition of the debris as sediments, the alkalies diminish greatly and of the two, potash is customarily the survivor. Sediments of a composition such as these analyses afford, would be extraordinary, whereas eruptive rocks not infrequently furnish parallels.

Granite. This rock as an acidic extreme of the syenite series has already been referred to. The field relationships of the specimen analyzed are best explained by this assumption. In the southeastern corner of the Elizabethtown quadrangle, there is, however, as already set forth a quite extended area in which granitic rocks are prominent. It has been mapped as a separate mass, although the evidence of its individual intrusive character is not clear. The subject is fully discussed under the topic of granites and related types. They have a widespread reddish color and yield percentages in quartz such as are possessed by the granites.

In one of the two localities which have been studied with the microscope the rock consisted of quartz and microperthite in great preponderance. There were a few shreds of biotite and hornblende, and rarely a grain of magnetite and a zircon. The rock was greatly crushed and strained. This is the specimen which furnished the analysis given as no. 1 under the syenites above.

A second, a reddish rock from the southeastern corner of the Elizabethtown sheet in the area mapped as granite, contained greatly predominating quartz and finely twinned plagioclase. It has already been mentioned under granites on a preceding page. Orthoclase could not be identified. A few decomposition products, believed to have once been bisillicates, and a few tiny zircons made up the slide. The minerals showed abundant evidence of strains and crushing.

Basic gabbros

This type of rock constitutes a large number of intrusions well distributed along the border of the anorthosites and the other rocks and sometimes in the anorthosites themselves. They are widespread throughout the eastern Adirondacks and, although far less large in amount than the anorthosites and syenites, are yet a characteristic feature of the local geology. They appear chiefly as

irregular masses of moderate size, and are sometimes demonstrably in dikes. More often they seem to be irregular, eroded sheets, knobs, or perhaps laccoliths. The abundant vegetation, the widespread faulting, the extended erosion and the metamorphism, have all served to mask the details.

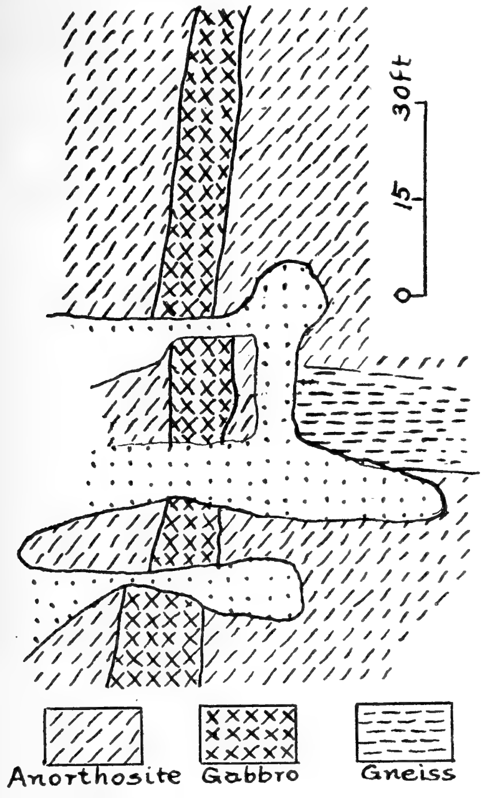

Fig. 8 Gabbro dike intruded in anorthosite and faulted. The gneiss is either an inclusion or a dike older than the gabbro, and greatly sheared. The locality is in Lewis in the northeast corner of Elizabethtown quadrangle.

The rocks are greenish black in color and rough upon weathered surfaces. The pitting from the decay and disappearance of the feldspar has left the augite and ever present magnetite projecting in little lumps. Where the gabbros appear in the beds of streams and beneath cascades, the rock is a rich green and affords most beautiful and instructive exhibitions of rock texture. It is comparatively rare that the gabbros are free from the effects of crushing and shearing. When, however, such specimens are found they present a coarse diabasic texture. The plagioclase crystals are tabular and on the fractured surfaces exhibit thin rectangular cross sections within whose network the dark silicates and the iron ores

are packed away. The ever present effects of pressure have almost always granulated the components and have turned feldspars, bisilicates and ores into lenticular interwoven masses. More complete crushing, often accompanied by apparent flowage, has given swirling, gneissoid foliation and in the extreme has developed a decided hornblendic gneis.. This curious and interesting variation of texture can be seen in the brook bottoms which enter the Boquet from the steep mountains on the west, and above Elizabethtown. The brook which comes in about 2 miles south of the village and along the contact of the gabbro and syenite and with a trap dike across its exit from the cliffs, gives very interesting exposures, and the same is true of Roaring brook a mile to a mile and a half from its mouth. The stringing out of the minerals may be in part a phenomenon of igneous flowage, but certain it is, that the textures vary greatly within short distances and the rock, whether molten or whether viscous from pressure, has not behaved as a perfectly hydrostatic body. Buttresses or masses unaffected by the flowage have remained in the midst of the generally plastic material.

The component minerals of the gabbro are chiefly plagioclase, augite, hypersthene, brown hornblende and titaniferous magnetite. The less common ones are olivine and biotite. A widespread member not truly original with the rock is garnet, which appears in the reaction rims in a very interesting and at times remarkable manner.

The plagioclase is a basic variety, labradorite or one even lower in silica. It is so charged with finely divided dusty inclusions that it remains practically opaque in its central portions even in very thin slides. The inclusions appear to be pyroxenic dust and minute green spinels, but they are so exceedingly small, and their optical properties are so disguised by the containing feldspar, that their sharp identity can not well be made out. Around the edges the feldspars become clearer, and next the reaction rims of garnet they are limpid and transparent and apparently are untwinned albite. The lime component seems to have been contributed to the garnet.

The augite is, in the thin sections, light green in color and appears to be of the ordinary variety, often seen in the gabbros. The hypersthene is widespread and frequently in sufficient amount to make the rock a norite. It is in no way remarkable. The hornblende is of a deep brown variety, and increases greatly in amount where metamorphism is more pronounced. Olivine is not specially abundant. So far as studied, many exposures may entirely fail to show it. It is pale green in color and customarily quite fresh. The titaniferous magnetite is richly distributed through the rock. It can be readily detected with the eye, and under the microscope

forms basic centers around which are grouped the bisilicates in especial richness. In several places the titaniferous magnetite has become sufficiently concentrated to attract attention as an iron ore. The ore yields about 40 per cent iron more or less, and can be best discussed under the topic iron ores. It is simply a portion of the gabbro mass with an unusual amount of the titaniferous magnetite. The feldspar fails but all the other components are distributed through the ore and appear in the thin section.

The reaction rims of garnet are very widespread in the gabbros, so much so that it is unusual to find the rock unprovided with them. They follow along the border lines between the feldspar and the more basic minerals, preventing the contact of the two, and giving a pinkish cast to the rock which is quite characteristic. The garnets at times manifest a curious tendency to develop projections like fingers out into the feldspar and seem to have formed from one twin lamella and not from those on either side.

A number of analyses of the gabbros were prepared several years ago in the laboratory of the United States Geological Survey, in connection with a paper by the writer, upon the "Titaniferous Ores of the Adirondacks."[1] They are reproduced here in order to give an idea of the chemical composition of the rock and to furnish a basis for recasting into the approximate percentages of component minerals. With these quoted analyses are one or two others from exposures not connected with ore bodies and only hitherto published in Bulletin 168, United States Geological Survey, page 37 under the work of the chemical and physical laboratories.

	1	2	3	4	5
SiO_2	47.88	47.16	46.74	44.97	44.77
Al_2O_3	18.90	14.45	16.63	15.40	12.46
Fe_2O_3	1.39	1.61	2.17	2.29	4.63
FeO	10.45	13.81	10.60	12.39	12.99
MgO	7.10	5.24	6.11	10.89	5.34
CaO	8.36	8.13	8.66	7.50	10.20
Na_2O	2.75	3.09	3.81	3.02	2.47
K_2O	.81	1.20	.86	.56	.95
H_2O-	.43	.48	.73	.65	.48
H_2O-	.18	.12	.12	.10	.12
CO_2	.12	.35	.07	.23	.37
TiO_2	1.20	3.37	2.54	1.18	5.26
P_2O_5	.20	.57	.33	.14	.28
S	.07	.14	.11	.06	.26
MnO	.16	.24	.26	.22	.17
NiO.CoO	.02	.02	.03	.02	......
V_2O_5		......	....	.02	......
	100.02	99.98	99.77	99.72	100.75

1 Wall rock of titaniferous magnetite. Split Rock mine, Westport. Analysis by W. F. Hillebrand.
2 Woolen mill 1 mile west of Elizabethtown. Analysis by W. F. Hillebrand. See above p. 40.
3 Gneissoid gabbro, 2 miles south of Elizabethtown. Analysis by W. F. Hillebrand.
4 Massive gabbro, same exposure as No. 3. Analysis by W. F. Hillebrand.
5 Wall rock of titaniferous magnetite. Lincoln Pond. Analysis by George Steiger.

[1] 19th An. Rep't. 1899. pt III. p. 377–422.

	1		2		3		4		5	
Or........	4.45		7.23		5.00		3.34		5.00	
Ab........	23.06	56.70	26.20	44.27	31.97	45.87	25.15	38.49	20.96	37.36
An........	33.64		18.07		13.90		13.34		16.40	
Kaolin....	3.10		3.43		5.42		4.65		3.60	
Calcite....	.20		.80		.10		.50		.90	
$CaO.SiO_2$..	2.67	13.41	6.96	19.89	11.25	11.98	3.48	6.66	12.53	32.71
$FeO.SiO_2$..	4.88		7.13		.....		1.19		8.32	
$MgO.SiO_2$..	5.60		5.40		.20		1.60		11.60	
$MnO.SiO_2$..	.26		.40		.53		.39		.26	
$2FeO.SiO_2$.	8.46	16.93	8.36	13.82	10.20	19.16	13.67	30.47	1.73	2.93
$2MgO.SiO_2$.	8.47		5.46		8.96		16.80		1.20	
Magnetite..	2.09		2.32		3.25		3.25		6.73	
Ilmenite...	2.13		6.23		4.62		2.16		9.73	
Apatite....	.34		1.34		.70		.35		.67	
Pyrrhotite.	.18		.35		.26		.18		.65	
Garnet....	.....		.....		.....		7.20		.....	
Spinel.....	.....		.....		3.13		2.13		.....	

	1	2	3	4	5
Plagioclase....................	$Ab_1An_{.8}$	$Ab_1An_{1.3}$	$Ab_1An_{0.8}$	Ab_1An_1	$Ab_1An_{1.5}$
Light colored minerals.........	64.45	55.73	56.39	46.98	46.86
Dark colored minerals.........	35.08	43.95	43.10	52.40	53.42

1 Wall rock of titaniferous magnetite. Split Rock mine, Westport. Analysis by W. F. Hillebrand.
2 Woolen mill 1 mile west of Elizabethtown. Analysis by W. F. Hillebrand. See above p.40.
3 Gneissoid gabbro, 2 miles south of Elizabethtown. Analysis by W. F. Hillebrand.
4 Massive gabbro. same exposure as no. 3. Analysis by W. F. Hillebrand.
5 Wall rock of titaniferous magnetite. Lincoln pond. Analysis by George Steiger.

In the quantitative system, no. 1 is class II Dosalane; order 5 Germanare; rang 4 Docalcic, Hessase; subrang 3 Persodic, Hessose.

Nos. 2, 3, 4 and 5 are all class III Salfemane; order 5 Gallare; rang 4 Docalcic, Auvergnase; subrang 3 Auvergnose.

In recasting the above analyses, nos. 1, 2 and 5 could be done in the normal way. That is, aside from the accessories such as magnetite, apatite, pyrrhotite, ilmenite and calcite about which there can be little doubt, the soda and potash were assigned to albite and orthoclase; the combined water to kaolin, and the remaining alumina used for anorthite. There then remained sufficient silica to care for the excess of lime as the bisilicate and for the ferrous iron and magnesia partly as unisilicates, partly as bisilicates. In nos. 3 and 4 this proved impossible, because if this course is followed for anorthite there is not enough silica to satisfy the remaining bases even as unisilicates which we know are not the sole dark silicates present. To obtain sufficient silica, the only feasible course was to reduce the anorthite, and for no. 3 a plagioclase molecule $Ab_1An_{0.8}$ was assumed. It became possible then to reach a solution. In no. 4 similarly Ab_1An_1 was assumed, and both the garnet and spinel molecules were called in. These assumptions have no particular advantage over the ordinary calculations of the highly ingenious quantitative system, except that we confine ourselves to making assumptions of minerals known to exist in the rock. Probably every one of these rocks had some garnet, to whose substance both anorthite and bisilicates contributed. Possibly

some of the ferric iron was in the bisilicates and it was not entirely combined in the magnetite. The calculation of the pyroxene does not tell us how much is hypersthene and how much is in the monoclinic variety. Probably some little alumina was in the pyroxene. Yet even with all these restrictions the final results in nos. 1, 2 and 5 are doubtless very near the truth and afford interesting general conclusions. Thus no. 1 is only 3 per cent higher in silica than no. 5. Yet the light colored minerals are almost 20 per cent greater in the former than in the latter. The excess of alumina in no. 1 is mainly responsible for this result, since by this we are able to care the better for lime in anorthite. It is striking that silica should fail to satisfy the bases in nos. 3 and 4 on the lines of the ordinary silicates, despite the fact that in these rocks its percentage exceeds that of no. 5, and but slightly yields to nos. 1 and 2. Mineralogical relationships in rocks, as indeed we have learned forcibly from the quantitative system, depend on other factors than the silica.

With all their shortcomings these recast analyses are nevertheless presented with the purpose of illustrating again the connection between chemical composition and mineralogical components.

Unmetamorphosed basaltic dikes

The last manifestation of eruptive activity and one which followed the general metamorphism, took the form of comparatively narrow basaltic dikes. They are quite widely distributed but not specially abundant in this area. They are members of an eruptive series which is widespread throughout the eastern and northern Adirondacks. Approximately 20 individuals or groups of individuals have been noted in the Elizabethtown quadrangle, and 16 in the Port Henry. These are undoubtedly but a small fraction of those existing and either concealed or unnoted. Wherever cascades reveal exposures for relatively long distances or iron mines have opened up the rocks underground the dikes have almost invariably been discovered. The great majority strike northeast. Of 32 accurate records, 19 lie between n. 35° e. and n. 70° e.; 6 are east and west and 4 nearly north and south. Only 3 are northwest. The northeast strike corresponds with the major structural breaks, and the dikes often appear in the broken and jointed rocks where exposed in the beds of brooks.

The dikes are mostly narrow, from 1 to 4 feet, but one has been met at 40 feet, and at the other extreme there are some only a few inches. Where the dikes tongue out to a feather edge, they

become a coaly black glass from the effects of chill, and always the borders are denser than the centers. One very interesting case has

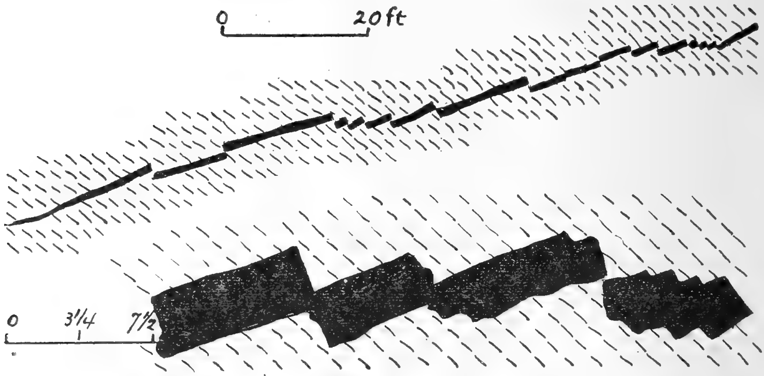

Fig. 9 Step-faulted dike in Walker brook, North Hudson

been found of one dike penetrating another and chilled by it. There were clearly two periods of intrusion in this instance and

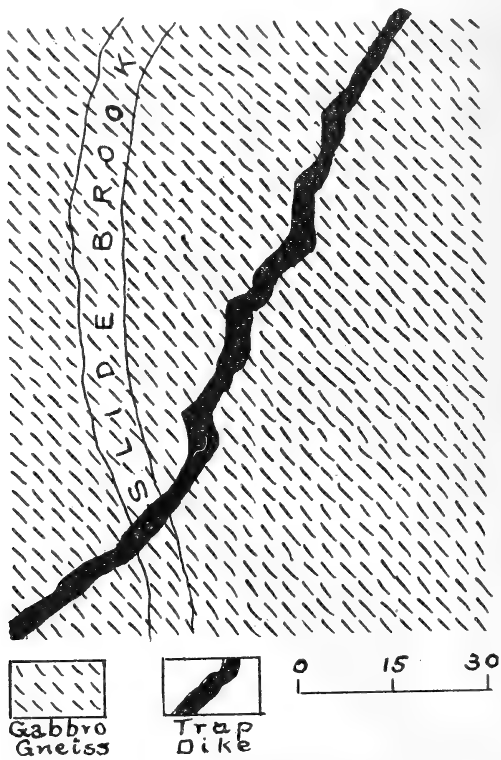

Fig. 10 Basaltic dike in an irregular and jagged crack on Slide brook. The dike strikes n. 15° e. and dips 10° east. The wall rock is gabbro of the Split Rock Falls type.

one followed long enough after the other to have permitted the first to quite thoroughly cool. The specimen came from a boulder in the bed of the Branch, 2½ miles west of Elizabethtown.

The dikes sometimes present extremely interesting exposures. Figure 9 was sketched in the north fork of Walker brook in the extreme southwest corner of the Elizabethtown sheet. It shows some very striking little faulted blocks of a dike in anorthosite. Presumably the dike was once continuous but in being broken and separated into the little blocks it held its sharply angular form while the anorthosite which is here much crushed and granulated, molded around it. Figure 10 shows a dike in a jagged crevice. Figure 7 is a map of a small dike which appears in the bed of the Branch just above the mill, about a mile or less on the stage road from the Windsor hotel to the Keene valley. It can be followed

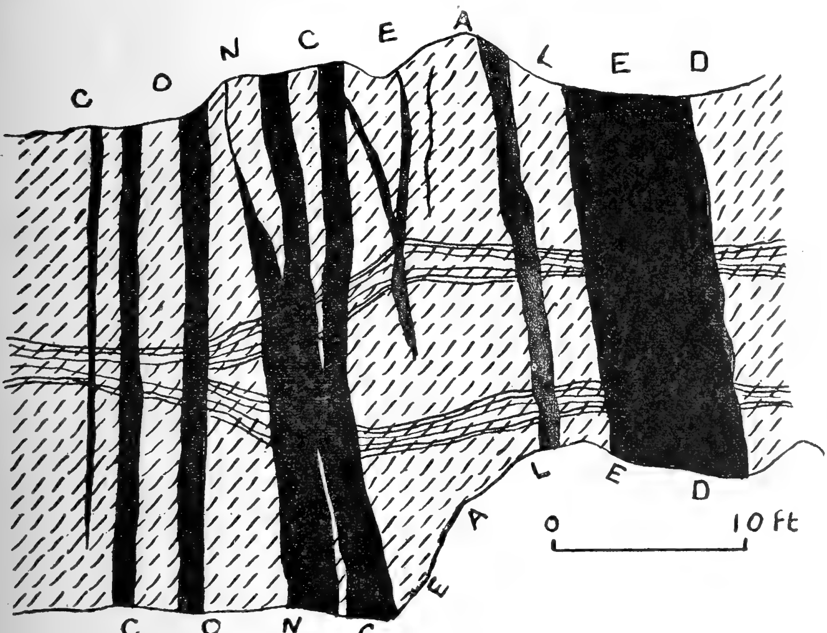

Fig. 11 Network of basaltic dikes in anorthosite and crossing the bed of Slide brook The dikes strike n. 45° w.

in the bed of the cascading brook from one end to the other. Figure 11 illustrates an interlacing network of dikes.

These dikes must have entered the wall rocks under very great pressure, and while in a state almost as fluid as water, must have penetrated every little crevice and crack open to them. They obviously followed the chief structural lines of weakness, and prob-

ably represent the last basic dregs from the great center of eruption which gave rise to the larger masses. In all cases noted they are massive and unmetamorphosed except from weathering. Undoubtedly they followed the great period of metamorphism but shared in some faulting.

Under the microscope the dikes are distinctly basaltic in their mineralogy. Plagioclase and augite are the chief minerals. Olivine occasionally appears, and magnetite is of course in every slide. In the thicker dikes and at the centers of those of moderate width the texture is diabasic; that is, the feldspars are long and narrow and well bounded. They form an interlacing network in whose interstices are the dark silicates. Toward the borders, however, the texture becomes porphyritic with a finer and finer ground mass until at the border the ground mass is a dense, black glass. The dike is cemented at times so tightly to the wall rock, or fused into it, that it breaks more readily elsewhere than along the contact. In several instances where cliffs are exposed along the course of a dike, fragments of the latter may be seen, still adhering tightly to the older walls, although the major part of the dike has disintegrated and disappeared. These relations appear at the dike shown just west of the highway and 2 miles south of Elizabethtown, and also in the one on the northwest corner of New pond.

No analyses have been prepared of the dikes within this area, but a selection is here given of those which have been published from neighboring localities. They will also be found compiled precisely as here given in New York State Museum Bulletin 95, page 350.

	1	2	3	4	5
SiO_2	43.41	44.51	45.46	46.73	50.89
Al_2O_3	19.42	19.99	19.94	16.66	15.39
Fe_2O_3	5.72	7.22	15.36	3.56	5.77
FeO	6.69			8.45	
MgO	5.98	8.11	2.95	8.12	7.60
CaO	9.11	8.15	8.32	8.03	8.75
Na_2O	4.39	5.24	2.12	3.73	5.67

1 Diabase summit of Mt. Marcy, Essex co. A. R. Leeds. N. Y. State Mus. 30th An. Rep't, p. 102.

2 Diabase. Upper Chateaugay lake, Clinton co. A. S. Eakle. Am. Geol. July 1893. p. 35.

3 Diabase. Palmer hill near Ausable Forks, Clinton co. U. S. Geol. Sur. Bul. 107. p. 26.

4 Olivine diabase. Belmont township, Franklin co., dike 13. Analyzed by E. W. Morley for H. P. Cushing. N. Y. State Geol. 18th An. Rep't, p. 120; and 20th An. Rep't, p. r79.

5 Olivine diabase Upper Chateaugay lake, Clinton co. A. S. Eakle, as under no. 2.

	1	2	3	4	5
K_2O	.47	2.60	3.21	1.64	2.72
H_2O	3.00	2.93	2.30	2.39	2.46
TiO_2	.35	....	....	.03	....
P_2O_5	....	....	....	.39	....
Cl	....	....	....	.18	....
F	....	....	....	.26	....
Cr_2O_3	....	....	....	.06	....
MnO	....	....	....	tr.	....
CO_2	2.00	....	....	....	....
BaO	....	....	....	.04	....
	100.54	98.75	99.66	100.27	99.25
O=Cl and F	....	....	....	.14	....
				100.13	

1 Diabase summit of Mt Marcy, Essex co. A. R. Leeds. N. Y. State Mus. 30th An. Rep't, p. 102.

2 Diabase. Upper Chateaugay lake, Clinton co. A. S. Eakle. Am. Geol. July 1893. p. 35.

3 Diabase. Palmer hill near Ausable Forks, Clinton co. U. S. Geol. Sur. Bul. 107. p. 26.

4 Olivine diabase. Belmont township, Franklin co., dike 13. Analyzed by E. W. Morley for H. P. Cushing. N. Y. State Geol. 18th An. Rep't, p. 120; and 20th An. Rep't, p. 179.

5 Olivine diabase. Upper Chateaugay lake, Clinton co. A. S. Eakle, as under no. 2.

	1	4
Or.	2.22	9.45
Ab.	37.21	31.44
An.	15.29	9.73
Calcite	4.50	....
$CaO.Al_2O_3.SiO_2$	13.28	11.34
$CaO.SiO_2$	....	5.34
$2MgO.SiO_2$	10.50	14.34
$2FeO.SiO_2$	5.51	9.69
Ilmenite	.62	....
Magnetite	8.12	5.11
Apatite	....	1.16
Water	3.00	2.39
Etc.	....	.57
	100.25	100.56
Light colored minerals	59.22	50.62
Dark colored minerals	38.02	46.98
Water	3.00	2.39

The recasting was only attempted for nos. 1 and 2 because in these alone was the FeO determined. The difficulty in carrying

it out lies in the assignment of the silica after the orthoclase and albite have been cared for. In order to have enough to combine with the bases, all the magnesia was necessarily assigned to olivine, as was the ferrous iron except what was required for magnetite. The remaining silica was then divided between anorthite and augite. For the lattter, the molecule $CaO.Al_2O_3.SiO_2$ was necessarily used with $CaO.SiO_2$. It is probable that this gives too little anorthite and that the magnesia and ferrous iron are not all in the olivine. If so, the necessary silica can only be found by assigning some soda to the pyroxene. There is undoubtedly some kaolin and chlorite, possibly also some serpentine, but there is no means of assigning the water. The proportions of light and dark minerals are doubtless near the truth.

Chapter 5

PALEOZOIC STRATA

Potsdam sandstone. This formation occupies nearly the whole of the Paleozoic fringe about Port Henry. It also constitutes a small fault block at the south end of the Westport area, and it further appears at the north end of the latter in the bed of Hammond brook in Westport village from beneath the Beekmantown beds.

The former extension of the Potsdam formation over all or the greater portion of the Elizabethtown and Port Henry sheets is clearly demonstrated by a small outlier observed by Professor Kemp far back in the mountains. Professor Kemp writes on this exceedingly interesting outlier:

The Potsdam outlier consists of cream-colored or yellowish quartzite, in beds of several inches thick. The strike is n. 20° w., dip 13°e. 12 feet are clearly exposed in one place with no bottom shown, and probably not less than 25 feet are present, perhaps more. The exposure extends 100 yards at least. It lies in the drainage of the Schroon river, down which and 12 or 13 miles to the south is a block of Beekmantown limestone on which is built the village at Schroon Lake post office. This is the nearest of the other Paleozoic exposures.

Another outlier farther north is indicated by the following observations of Professor Kemp:

Again in the area colored for basic anorthosite and 1½ miles northwest of Elizabethtown and near the boundary with Lewis, loose slabs of Potsdam sandstone have been found in such abundance that they have been used for building stone in one or two of the finest residences in Elizabethtown. Careful search along a small affluent of Barton brook revealed many loose pieces, strongly suggesting an outlier in place, but no actual ledge could be located.

The exposures in the neighborhood of Port Henry are by far the most interesting of all, since here the contact with the Precambric rocks, the original surface of deposition of the latter and the basal beds of the Potsdam are shown. The main part of the block is strongly tilted to the east and so deeply eroded in its northern part that the irregular Precambric surface is exposed below the Potsdam sandstone in several places. The best of these exposures is in the southern part of Port Henry where West street crosses a brook. Here the Potsdam sandstone begins at its contact with the Precambric rocks with about 3 feet of conglomerate of arkose character, consisting prevailingly of dark quartz pebbles, smaller grains of fresh feldspar and a yellowish loamy-looking matrix. The quartz pebbles are mostly small and never surpass half an inch in diameter. This is followed by reddish sandstone with irregular conglomeratic bands or streaks, measuring about 20 feet and above this follow about 10 feet of grayish white sandstone with fine grained silicious matrix and many floating, large, rounded quartz grains. This is overlain by the typical white to yellowish Potsdam sandstone. This basal portion is very indistinctly bedded but exhibits clear evidence of current action such as cross striae and plunge structure. Another contact of the Precambric and Potsdam is shown at another inlier along the lower course of McKenzie brook below the highway bridge. Here the bottom layer consists of 3 feet of greenish gray arkose sandstone with scattered pebbles of quartz of the size of cherries, over which beds of fine grained sandstone directly follow. In a third place, also along McKenzie brook, a rather fine grained reddish sandstone, about 20 feet thick, is found to rest in an apparently original depression of the ancient sea floor. A few thin conglomerate streaks near the contact are the only indications of the nearness of the great unconformity. It is thus evident that the coarse basal conglomerate seen in other places had here been worked up by wave action until only a small amount of larger quartz pebbles was left. Nevertheless the wave action was not sufficient to completely plane the sea floor, for the latter is proven to have been very irregular at the time when the basal conglomerate was deposited, by the hummocks of Precambric rocks protruding through the Potsdam sandstone as well as by the presence of original channels in the floor now filled with Potsdam sandstone and exposed in places along McKenzie brook.

The base of the Potsdam formation in this area differs not only from that of others in the slight development of the basal con-

glomerate but also in the absence of the deep red, hematitic arkose sandstones so abundant in the basal portion of the Potsdam in Clinton county and on the north border of the Adirondacks. Altogether the sandstone of this area resembles in its physical characters more the middle and upper divisions of the Potsdam as distinguished in the typical sections at Keeseville and Potsdam by Van Ingen and Cushing, than it does the lower portion. It is best exposed at Port Henry in Bond's quarry above the Mineville railroad track and in the cut of the Delaware and Hudson Railroad north of the station. In the former place, as also along the upper McKenzie brook, white and yellowish fine grained, partly heavy bedded and partly slabby sandstones with occasional shaly bands prevail. By universal cross bedding, floating large sand grains, ripple-marked surfaces (beautifully displayed along McKenzie brook) and intercalations of brecciated beds it is indicated that these sandstones which would seem to correspond to the middle portion of the Potsdam[1] were deposited not far from the shore line. In the railroad cut about 60 feet of whitish gray sandstone in one-foot courses are exposed that present the typical and usual appearance of the Potsdam sandstone. These beds are within a third of a mile of the exposure of the Beekmantown beds at the tunnel and since they dip in that direction, the interval of drift-filled valley is inferred to be eroded in the remainder of the Potsdam series.

The isolated exposure of Potsdam beds in the fault block at the south end of the Westport Paleozoic area is again composed of evenly bedded brownish, yellow and white sandstones corresponding to the higher portions of the formation. About 100 feet of these are exposed in the railroad cut. The third exposure of Potsdam sandstone in the portion of the quadrangle here discussed is in the village of Westport above the highway bridge and along the shore. Only about 35 feet, consisting of whitish sandstone in one-foot beds followed farther up by heavier beds of brown sandstone, are exposed.

While the evidence on the development of the Potsdam formation in the area under discussion, owing to its faulted and much eroded condition is very incomplete and time was lacking for a more exhaustive investigation of the formation, it seems fairly certain that the lower Potsdam, and probably also the upper Pots-

[1] The reported finding of a small trilobite, probably Ptychoparia minuta, on upper McKenzie brook, may also indicate, however, the presence of beds equivalent to a part of the upper 350 feet of the Ausable Chasm section, i. e. of upper Potsdam beds.

dam beds, are here not as fully developed as in Clinton county and that the formation as a whole does not attain the great thickness it has farther north.

Beekmantown formation. The Beekmantown formation has been found during this investigation to be well exposed along the shore from Cold Spring bay to Cole bay, in the Westport area. The section begins with the division A of the Beekmantown at Cold Spring bay, south of Westport, the transition beds to the Potsdam farther north being hidden from view by drift. Owing to the west to south dip of the beds the other divisions are successively brought up in the shore cliffs and their characteristics can be studied in detail. Care must, however, be taken since low anticlines and faults have caused repetition of beds and the disappearance of portions of the section, especially in D which therefore is incompletely exposed.

The greater part of divisions A and B is probably covered, but division C which occupies the lake shore from the promontory east of Cold Spring bay past Barber point to the point east of Cole island is splendidly exposed in all its subdivisions; the only important disturbance appearing at Young bay where probably a minor fault passes out and south of Barber point where a low anticline causes a repetition of the beds. Of especial interest are beds of coarse breccias in C_2, containing angular blocks of the preceding divisions, some 2 feet in diameter. These brecciated beds are repeated several times. C_3 which is exposed at Barber point, is a sandstone much resembling the Potsdam sandstone and covered on the surface with great numbers of spirally curved worm casts. Below the light-house C_4, the magnesian limestone no. 2 is exposed. This also is brecciated and is followed again by the worm tube marked sandstones of C_3 which extend for half a mile south of Barber point and are followed by the magnesian limestones of C_4 which here, as in the Shoreham section of Vermont,

[1] We have here adopted the subdivision of the Beekmantown (Calciferous) formation in five members (A, B, C, D and E), first proposed by Brainerd and Seely [Am. Mus. Nat. Hist. Bul. 3:1, p. 2–3; *see also* Cushing. N. Y. State Mus. Bul. 95, p. 361]. Division A consists in Brainerd and Seely's type section at Shoreham in Vermont of 310 feet of dark iron-gray magnesian limestone, that in some beds approaches a sandstone; division B of 295 feet of dove-colored limestone; division C (350 feet) of magnesian limestone and sandstone; division D (375 feet) of blue and drab limestone and sandy limestone; and division E (470 feet) of fine grained magnesian limestone with thin layers of slate near the top.

are characterized by patches of black chert, square yards in size. At the point northeast of Cole island the beds of division D begin with bluish gray massive limestones, weathering with irregular surface owing to the dolomite content. This subdivision D contains also many indistinct sections of Ophileta. The section continues westward to Cole bay, at the northern boundary of which, opposite Cole island D_4 characterized by thin, tough, slaty layers of limestones is shown. Back of Cole bay in the falls of Stacy brook over 100 feet of division E are finely exposed. They appear as drab to bluish gray magnesian limestones, regularly divided into one-foot beds with shaly intercalations. The upper beds abound in crinoid joints; otherwise fossils seem to be rare in this locality.

South of Cole bay the contact of the Beekmantown and the Chazy can be followed for a long distance. Since here this contact, which is rarely seen, is well exposed, we will insert the details of the section, which have been studied in company with Dr E. O. Ulrich:

10′	Conglomerate, heavy bedded, crystalline, bluish black limestone (Chazy) with Phylloporina incepta, grading upward into the banded limestone with Maclurites. At the base are irregular crystalline 6′ layers, full of fossils: Phylloporina incepta and numerous ostracods, small and larger trilobites, fragments of Orthis costalis and other brachiopods. Most of the beds (lower half) more or less conglomeratic. Base of Chazy
2′	Even blue, calcareous shale. No fossils
2′ 6″	Fine grained, earthy, mottled, light and darker gray bluish impure limestone
2′ 6″	Thin, light bluish shale with thin earthy and sandy limestone intercalations. Full of small branching fucoids
8′	Black, whitish weathering, blocky, impure, barren, bluish gray dark limestone with shale partings. Lighter colored, finely granular to every compact, limestone in layers of 3 inches to 2 feet

It will be seen by this section that the lithologic change from the Beekmantown to the Chazy is abrupt. Since the Chazy begins with conglomeratic beds, there is little doubt of an unconformity at its base.

Another smaller series of outcrops has been observed in the Westport area on the other side of the plain of Champlain clays near the foot of the line of bluffs of Precambric rocks marking the

direction of the master fault of the region. The most important of these are found along the highway leading along the base of the fault scarp near the upper stretches of Beaver brook and along its branches.

The Port Henry area of Paleozoic rocks contains at its north end a most interesting exposure of Beekmantown rocks at both ends of the railroad tunnel and especially along the shore to the east of the tunnel and north of the same as far as Craig harbor. About 80 feet of division A are exposed in the cliff through which the tunnel has been driven. These, mostly the dark iron-gray dolomites, characteristic of the division, exhibit heavy beds at the base, that consist of rounded quartz grains cemented by a dolomitic matrix and representing the basal beds of the formation or at least indicating closeness to its base. The beds are frequently cross-bedded, some show very irregular surfaces and bedding planes and others display an irregularly nodular structure, while the beds resting on irregular surfaces contain pebbles of the underlying courses. The beds of this subdivision bear here evidence of much disturbed disposition, although much of the brecciated appearance is undoubtedly due to later crushing of the beds [*see* below p. 91]. In the railroad cut to the north of the tunnel the upper beds of division A, marked by black chert bands, are seen, and beyond a depression follow the purer limestones of division B which extend as far as Craig harbor and are here quarried extensively to be used for flux on account of their relative purity. This outcrop complements to a large extent that of the Westport area, exhibiting the lower beds which there are only partly exposed. Neither of the divisions showed any traces of fossils save fragments of linguloids observed by Kemp and Matthew in the arenaceous basal beds in the railroad tunnel, and the much disturbed condition of the beds did not allow of reliable measurements of their thickness.

The third appearance of Beekmantown beds on the sheet on this side of the lake is that on Crown Point peninsula. Here only three outcrops could be found, one on the shore of Bulwagga bay, another near the road and a third in the middle of the east shore. The first, as originally described by Brainerd and Seely and more fully elaborated by Raymond, contains but the barren top layers of the Beekmantown, while the others are fossiliferous outcrops of the divisions D and E.

In the first two outcrops only a few feet of a light-gray dolomite are shown which are directly followed by the basal beds of the

Chazy. The other outcrop comprises 150 feet in one continuous section and amounts altogether to about 300 feet of rock, consisting mostly of steel-gray to bluish gray compact dolomitic limestone with rough surfaces on the weathered beds, suggesting D_1, and sandy limestone in thin beds weathering on the edges in horizontal ridges and denoting D_3. Indistinct sections of gastropods were observed in several beds.

Although it would seem desirable to map separately the divisions of a formation aggregating 1800 feet in thickness, the scattered position of most outcrops and the obvious presence of numerous tectonic disturbances, indicated by the varying dips, would not have allowed anything approaching correctness in the drawing of the boundaries. Only on the east side of the Westport area, along the lake shore the boundaries of the divisions could be drawn in and continued according to the prevailing north northwest strike in this region for some distance. But the western continuations of these boundaries are entirely lost under the Champlain clays and the accompanying description will suffice to locate the divisions along the shore. We have also refrained from separating as a distinct unit on our maps the Cassin formation from the rest of the Beekmantown, although its recognition as a distinct unit is urged by Professor Cushing, apparently on good grounds. This Cassin formation is to comprise the upper portion of D and all of E. In the areas here under discussion it is exposed around Cole bay, between the highroad and the fault scarp near the northern branches of Beaver brook, and it also is represented in the outcrops on Crown Point peninsula.

It is also probable that the division A, amounting to over 300 feet of rock, will in time be separated from the Beekmantown by Dr Ulrich who considers it the eastern representative of a separate formation having possibly even the value of a system that is fully developed in the Mississippi basin. At any rate, there is good evidence that a strong unconformity separates division A from the rest of the Beekmantown. The rocks of A are best exposed in the cliff north of Port Henry through which the tunnel passes. Less favorable exposures are found at Cold Spring bay and near the base of the fault scarp in the Westport area. The northernmost of these exposures is a small abandoned quarry ½ mile north of Westport and ¼ mile east of the railroad track.

Chazy formation. The Chazy is exposed in complete sections in two places, viz, in the Westport area where the section extends

from the contact with the Beekmantown beds, south of Cole bay, along the shore to Mullen bay, and on Crown Point peninsula. Scattered outcrops occur also in the Westport area along the highway. The section of Crown point has been first described by President Brainerd[1] who found a thickness of 305 feet and believed he recognized all three of the Chazy divisions, distinguished in the type section. He gives the following section in ascending order:

			FEET
A	1	Sandstone and slate interstratified..............	23
	2	Impure limestone containing Orthis platys..	25
B		Beds containing Maclurites magnus.......	200
C	1	Dark gray massive limestone, weathering in dark stripes an inch wide, containing Bucania sp. und.	40
	2	Tough, silicious and magnesian rock, passing into a two-foot bed of pure sandstone..............	17
		Aggregate thickness....................	305

This section was later on most carefully investigated by Dr Raymond[2] who, by means of the fossil evidence, concluded that only the middle division B (which he terms the Maclurites magnus division) is present, the Chazy sea reaching so far south only during the hight of the invasion in middle Chazy time. In a later publication[3] the following summary of his investigation of the Crown Point section is given:

A_{1-4}. Thick beds of slaty shale with occasional bands of hard, fine grained sandstone. Fucoids numerous.

25 feet 2 inches=25 feet 2 inches

Lingula brainerdi, a

A_{5-8}, C_1. Impure blue limestone, rather thin bedded.

91 feet 10 inches=117 feet

Plaesiomys platys, c	Camarella longirostris, r
Hebertella vulgaris, c	C. varians, r
Rafinesquina alternata, c	Maclurites magnus, r
R. incrassata, c	Isotelus harrisi, c
Zygospira acutirostris, r	Leperditia canadensis, c
Orthidium lamellosum, r	L. limatula, r
Lingula *sp.*, r	Eurychilina latimarginata, r

Concealed 34 feet=151 feet

[1] Geol. Soc. Am. Bul. 1891. 2:300.
[2] Am. Pal. Bul. 14. 1902.
[3] Carnegie Mus. Ann. 1906. v. 3, no. 4, p. 551.

B_{1-4}. Impure, thin bedded fine grained limestone.

16 feet 6 inches = 167 feet 6 inches

Plaesiomys platys, c	Bucania sulcatina, c
Rafinesquina alternata, r	Maclurites magnus, r
R. champlainensis, c	Ctenodonta peracuta, rr
R. incrassata, rr	Isotelus harrisi, r
Camarella varians, rr	Thaleops arctura,[1] rr
Raphistoma stamineum, r	Leperditia limatula, c
R. striatum, rr	

Concealed 31 feet = 198 feet 6 inches

B_{6-16}, C_{3-12}. Impure, rather shaly limestone interstratified with heavy bedded, fine grained blue limestone.

80 feet = 278 feet 6 inches

Palaeocystites tenuiradiatus, c	Raphistoma stamineum, c
Monotrypella *sp.*, r	Bulcania sulcatina, c
Rhinidictya fenestrata, rr	B. bidorsata ?, c
Plaesiomys platys, c	Lophospira perangulata, r
Rafinesquina alternata, c	L. *sp. ind.*, r
R. champlainensis, c	Maclurites magnus, c
R. incrassata	Orthoceras *sp. ind.*, r
Camarella longirostris, r	Plectoceras *sp. ind.*, r
C. varians	Bathyurellus minor, r
Ctenodonta peracuta, rr	Isotelus harrisi, c
C. dubiaformis, rr	I. obtusus, r
Clionychia montrealensis, r	Thaleops arctura, r
Archinacella ? deformata, r	Pliomerops canadensis, rr
A. ? propria, r	Leperditia canadensis, c
Eccyliopterus fredericus, r	L. limatula, c
E. proclivis, r	Eurychilina latimarginata, r
Raphistoma striatum, r	

C_{13-14}. Very hard, blue gray magnesian limestone, weathering so as to show alternating light and dark stripes about an inch wide.

24 feet 6 inches = 303 feet

C_{15}. One layer of coarse grained sandstone in which there are many cavities, as though fossils had been dissolved out.

2 feet = 305 feet

C_{16}. Hard, magnesian limestone containing many large water-worn sand grains. 1 foot = 306 feet

Plaesiomys platys, r	Raphistoma stamineum, r
Camarella varians, r	Isotelus harrisi, c

[1] Dr Raymond cites this form as Thaleops ovata, since at the time he considered Hall's Illaenus arcturus as a synonym of Thaleops ovata Conrad. He has, however, later [Ann. Carnegie Mus. v. 4, no. 3. 1908, p. 248] separated again the Chazy and the Trenton forms, referring Illaenus arcturus also to Thaleops.

It is added that the section like that of Valcour island begins with a basal zone with Lingula brainerdi which, however, is not considered as representing "one horizon holding a definite place in the time scale, but as a tangential sandstone marking the base of the invading sea" and that the fauna is chiefly a brachiopod one, characterized by Rafinesquina champlainensis, Rafinesquina incrassata, Plaesiomys platys, Camarella varians, Raphistoma stamineum, Maclurites magnus, Isotelus harrisi, Thaleops arctura and Leperditia limatula. Four of these, viz, Rafinesquina champlainensis, Plaesiomys platys, Maclurites magnus and Leperditia limatula are cited as characteristic of the second or Maclurites magnus fauna at Valcour island.

The base of the Chazy is exposed at the east shore of Bulwagga bay where a few feet of the subjacent Beekmantown formation are seen. The Maclurites are observed here to come in directly above the basal 25 feet of slates and sandstone. Only about 50 feet are exposed along this shore in continuous section. The middle and higher beds are excellently shown along the shore, west of the light-house and in the pastures back of the shore. The last 26 feet which are best exposed west of and within the fort are peculiar in several respects. Most striking among these and all Chazy beds in this section are the white and black banded limestones (C_{13-14}), the bands, which appear on weathering, exhibiting in many layers fine examples of brecciation and recementation of the broken fragments, also oblique striation and plunge structure and other evidences of deposition in turbulent waters.

The Chazy is brought up again by a fault close to the southern boundary of the sheet. It is also here characterized by its fauna, notably numerous specimens of Maclurites magnus, as belonging to the middle division.

The section in the Westport area is not so easily accessible since, for the most part, the rocks are only exposed in a vertical cliff along the shore. Several outcrops appear also farther inland, along Beaver brook and the highway. Near the top several beds are found that either are not exposed or absent in the Crown Point section. One of these consists of unfossiliferous heavy bedded limestone with a basal bed of crinoidal limestone containing numerous large sand grains and composed in places nearly entirely of a small apparently new Camarotoechia. The base of the formation is well exposed, resting on the Beekmantown, south of Cole

bay; and likewise the top in a bed of magnesian limestone with many streaks of sand grains and few fossils. Five feet of this limestone are exposed in the point bounding Mullen bay on the east.

Black River group.[1] The Chazy is followed in the Crown Point section by 5 feet of dove-colored limestone which in part strikingly resembles the "Birdseye" or Lowville limestone to the south and west of the Adirondack plateau and also contains the characteristic vertical worm tubes (Phytopsis tubulosus Hall). This bed which is exposed outside the fort at the north entrance has been considered as representing the Lowville formation in the Champlain basin. Since, however, the writer found 15 feet above its top, in a bed of the "Black River formation," numerous typical specimens of Tetradium cellulosum[2] which in the Black River and Mohawk regions is the most characteristic fossil of the Lowville limestone, and as far as we know is there restricted to it, it is possible that the 5 feet of dove-colored limestone represent only a part of the Lowville formation and that a portion or all of the "Black River" of this section is equivalent to the Lowville. Indeed, it is claimed by Dr Ulrich that all of the "Black River" limestone of the Champlain valley is older than the Watertown limestone and is to be correlated with the Lowville formation. In the Westport area the dove-colored limestone has not been found.

A careful section of the "Black River" of Crown Point peninsula with fossil lists is given by Dr Raymond in the before cited paper. Two zones are distinguished, one, 7 feet of lumpy, black and heavy bedded limestone with a pelecypod fauna, and a second, 55 feet of lighter colored rock containing a brachiopod and crustacean fauna. The lower 24 feet of the latter portion are coarse grained while the remainder is fine grained. The lowest 15 feet of these beds in this section were found by us to contain chert in numerous nodules and even in continuous layers and the inference itself suggests that this "Black River" corresponds to the cherty limestone or the Leroy member of the Lowville formation.

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[1] The Black River group, as now understood by this survey, comprises the Lowville limestone, the Watertown limestone (formerly the Black River limestone and the Amsterdam limestone).

[2] Not listed by Raymond. There occur also in this horizon Hormoceras tenuifilum, Lituites and Oncoceras sp.; also not listed in the previous publications.

As the most characteristic fossils of the Black River group in this locality are cited by Raymond:

Maclurites logani *Salter*
Plectorthis plicatella *Hall*
Strophomena incurvata *Shepard*
Leperditia fabulites *Conrad*
Zygospira recurvirostris *Hall*
Stromatocerium rugosum *Hall*
Columnaria alveolata *Goldfuss*[1]

We have also observed some of the cephalopods so characteristic of the Black River beds at Watertown, notably Hormoceras tenuifilum and Plectoceras sp. (probably undatus). They were associated with Tetradium cellulosum and Orthoceras rectiannulatum, two typical Lowville fossils at Watertown but they appear also in the Watertown region already in the Lowville beds.

The lithologic characters of the Black River rocks at Crown point and in the Westport area are for the most part strikingly like those of the Watertown limestone at Watertown, in the fineness of the grain, the dark color and fine veining as well as the peculiar small blocky weathering.

In the Westport area the belt of Black River limestone begins at Mullen bay as indicated by a big angular boulder that has obviously been transported but a short distance and contains a large colony of Columnaria ?halli.[1] The belt strikes thence north-northwestward in the direction of Beaver creek and is exposed in two places in the creek bed, at one of which large specimens of Maclurites logani and of Stromatocerium can be seen.

Trenton limestone. Only the lower portion of the Trenton limestone is exposed in either the Westport area or Crown Point peninsula and this consists in both localities of thin bedded, slabby, mostly impure, very fossiliferous limestone with shaly partings. On the Crown Point peninsula there are 88 feet exposed, the remainder of the formation, which on the opposite shore in Vermont attains 314 feet, being hidden under the waters of Bulwagga bay. Raymond has distinguished several fossil zones in the Trenton, the lowest one of which is that of Raphistoma lenticulare comprising 4 feet 9 inches, separated from the Black River by a covered interval of 4 feet. It is followed by the Parastrophia

[1] As pointed out by Nicholson [Palaeozoic Tabulate Corals, 1879, p. 200], Winchell and Schuchert [Geol. Minnesota, v. 3, pt 1, 1895, p. 85], the Columnaria alveolata of American authors is not identical with Goldfuss's species and should be known as Columnaria ? halli Nicholson.

hemiplicata zone of T. G. White, (20 feet 9 inches), and this in turn is overlain by beds characterized by Trinucleus concentricus (about 20 feet) and the last 7 feet contain abundant fragments of Asaphus platycephalus.

South of Mullen bay in the Westport area, Trenton beds containing Parastrophia hemiplicata come up for a short distance along the lake shore, and the shingle farther south as far as the Potsdam outcrop is also nearly entirely composed of Trenton limestone slabs.

About 40 feet above Mullen bay in the railroad cut and along the road other small outcrops and masses of Trenton boulders are found. Some of these indicate the presence of the zone of Trinucleus concentricus. Finally the Trenton reappears again close to the fault scarp of the Precambric below the mill dam on Mullen creek with an outcrop of about 40 feet of impure limestones and alternating shales, the former containing the common brachiopods and Calymmene senaria, the latter a Diplograptus of the amplexicaulis type.

Trachyte dike. On the northern side of Cole bay, in Westport, there is an east and west dike of the trachytic rock, to which the special name of bostonite was given years ago. It cuts the Beekmantown limestone, but inasmuch as the same kind of igneous rock is elsewhere found penetrating the Utica slate, it undoubtedly marks a post-Ordovicic outbreak. Full details of these and associated eruptives will be found in the citation below.[1] The dike at Cole bay is a pale, gray felsitic rock, when unweathered, but is dark brown on the exposed surfaces. In thin section it presents a mass of tiny feldspar crystals, apparently orthoclase. The structure is strongly trachytic; that is, the little rods are interlaced and more or less parallel, with occasional flowing arrangement. No dark silicates remain, but a few rusty decomposition products suggest their former presence but in very small amount. No special analysis has been made, but those which have been prepared from other dikes lead us to believe that the silica is in the neighborhood of 60 per cent; the alumina 20; the potash and soda about 5 each; while the other components make up the balance. This dike is the most southerly of the bostonites thus far discovered. These peculiar dikes are rare types of eruptives and possess much petrographic interest.

[1] Kemp, J. F. & Marsters, V. F. The Dikes of the Champlain Valley. U. S. Geol. Sur. Bul. 107.

Chapter 6

STRUCTURAL GEOLOGY

Faults

Faults are of more than usual importance in the Adirondacks and the Champlain valley. They have been frequently and necessarily referred to in the opening description of the general relief. While the discordance produced by these displacements can not always and can not easily be demonstrated in the ancient crystallines, yet the tilted block character of the topography, the frequency of precipitous escarpments, the innumerable cross gulches along the crests of the ridges and the crushed and sheeted rock revealed by cascades in the brooks, all leave no alternative to the observer other than to believe in the general presence of these dislocations. There are, however, some positive forms of evidence which are more tangible, and it will be the purpose here to pass them in review.

Faults in the Paleozoic strata. Dislocations in the Paleozoic rocks have long been known and outside the present area are exhibited with diagrammatic clearness. They have been matters of record since the early work of Ebenezer Emmons, and in Chazy township, north of Plattsburg have been mapped and studied by Professor Cushing.[1] Near Port Henry and Westport they are not so clearly exhibited between individual members of the Paleozoic as they are farther north, but as between the Paleozoics and the older crystallines, they are well known.

The clearest case is afforded by the block of Beekmantown limestone, just north of Port Henry. As one passes through the two tunnels and across a small inlet, a block of this silicious, magnesian limestone is encountered which rises 100 feet or more above the lake. It is extensively quarried for flux for the Port Henry blast furnace and also for macadam. It has a very flat dip of 10 northeast and a strike of n. 55° w. If projected across the little embayment called Craig harbor on the map, it would abut abruptly against the Grenville. There is obviously a fault which causes the discordance and which passes northeast and southwest. The sheeting and crushing of the rock have given rise to the embayment, which has been worked back by the waves through the broken rock.

Another significant feature is found in the prevailing dips of the Potsdam and later strata. They are almost or quite always in-

[1] Cushing, H. P. Faults of Chazy Township, Clinton County, N. Y. Geol. Soc. Am. Bul. 1895. 6:285.

clined at low angles downward toward the next exposure of the Precambric, whereas if they were resting upon the latter in a depositional relation, they ought to slope upward to them. If, however, dropped by faulting, they would readily assume the relations observed.

Faults in the Precambric rocks. Faults are sometimes shown by the brecciated condition of the ancient crystallines. Figure 12 is a sketch to scale of an exposure of anorthosite south of the road, and near the Woolen mill, a mile or less west of Elizabethtown, where the exposures shown in figure 7, page 41, were mapped. The star upon this last named figure shows the exact spot. The

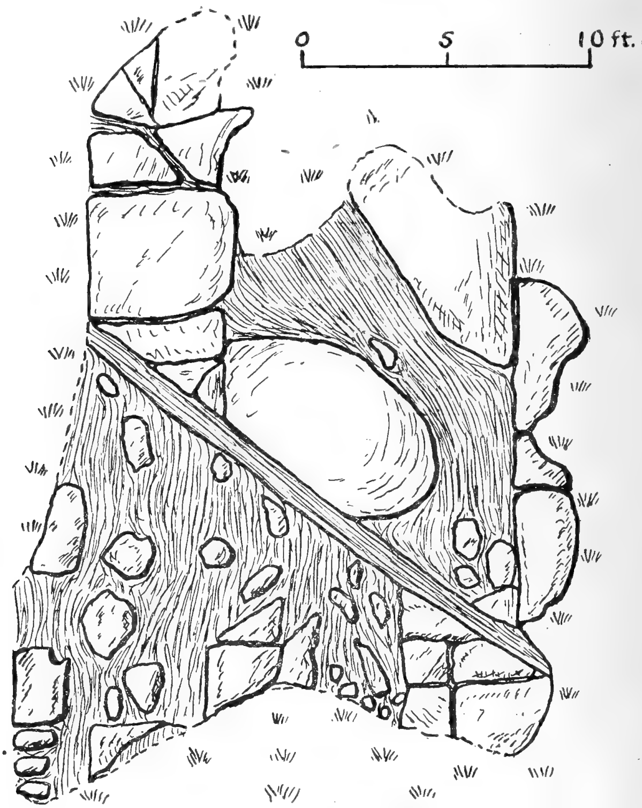


Fig. 12 Faulted and crushed anorthosite near Woolen Mill 1 mile west of Elizabethtown. The exact locality is shown by a star in the lower part of figure 7.

anorthosite has been crushed to a blocky breccia whose larger pieces are embedded in a sheared and schistose matrix derived from the comminuted particles. Besides the general crush, it would appear as if the upper portion of the diagram had been moved northwest

about the width shown, making the marked secondary sheared band which crosses it. The broken blocks in the lower right-hand and upper left-hand corners appear to correspond fairly well.

Brecciated exposures such as this have been met from time to time elsewhere. A quarter of a mile north of Cheever dock on Lake Champlain, and in granitic gneiss of the syenite series, there is another one beautifully exposed in the cuts of the railway. The fault has broken the brittle gneiss to a mass of angular bits, of which the individuals range up to 2 or 3 inches across and are cemented by finely crushed and chloritized material. In these brecciated exposures it is not always easy to detect the exact line of movement, since the result is chiefly the brecciation, but the attendant sheeting in the case just cited runs northeast.

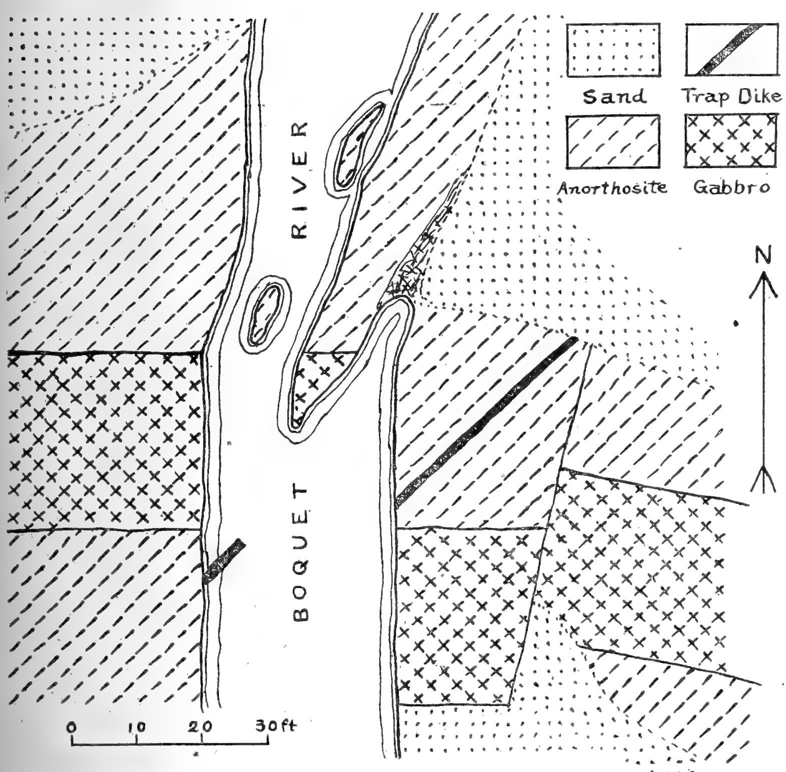


Fig. 13 Faulted gabbro and basaltic dikes in anorthosite, northeast corner of Elizabethtown quadrangle

Occasionally a fortunate combination of contrasted formations and faulting gives a clue to the nature and amount of the displacement. One such case is to be seen in the bed of the Boquet river

where the highway crosses it by a ford in a northeasterly direction and in the extreme northeast corner of the Elizabethtown quadrangle. This is illustrated in figure 13. The country rock is anorthosite which has been cut bv an east and west gabbro dike, 27 feet wide. Still later but before the faulting a narrow black trap dike penetrated both rocks with a northeast strike. The complex was then dislocated by two faults of which the westerly one moved the two dikes to the south about the width of the gabbro, and the more easterly moved the eastern prolongation about 10 feet back to the north. The figure gives the actual exposures, and where no rock symbol appears they are beneath the stream gravels. The trap dike appeared to terminate against the western bank, but no appreciable faulting was evident.

Figure 14 illustrates all that can be seen of a horizontal band of black hornblendic rock in the white Grenville marble, a hundred yards north of Cheever dock. This is believed to be a dike or narrow sheet, which, 6 feet in width, penetrated the limestone. It has been so broken that only three blocks remain visible and two of these are separated by 60 feet of an interval. The limestone has molded itself into the interval, obviously while plastic under pressure, illustrating those flowage phenomena which led Professor Ebenezer Emmons to consider the limestone an igneous rock.[1]

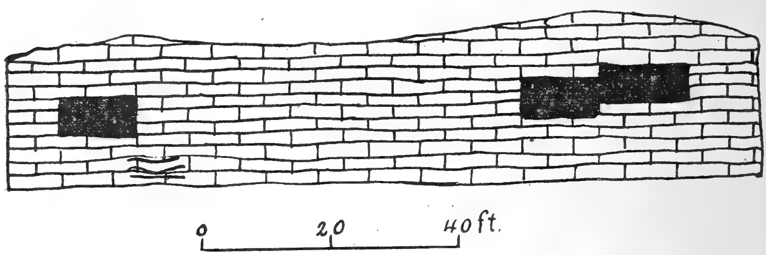


Fig. 14 Faulted blocks of black hornblende schist, presumably intrusive and now in Grenville limestone, just north of Cheever dock, Port Henry

Much the same thing is shown in plate 11 from a photograph in the limestone quarry south of the Pilfershire mines and just east of Barton brook. A sheet similar to the last has been broken into three pieces, of which the middle one has been pushed upward by the viscous limestone.

In the mines we find the best cases of faulting and the ones most clearly shown. Fortunately while the Cheever mine was being

[1] Geology of the Second District. N. Y. State Nat. Hist. Sur. 1842. p. 37.

operated in 1880, it was visited by Bayard T. Putnam as agent for the Tenth Census. Putnam was a most careful observer, who combined the keen sight of the geologist with the habits of record of the engineer. He plotted a cross section of the Cheever ore shoot, which shows it to be broken by nine little faults, all normal ones, although dipping first in one direction and then in another. They ranged from 28 to 78 feet apart and revealed displacements varying from 1.5 to 31.1 feet.[1] Some years after Putnam's visit the workings encountered a much larger fault which is stated to have cut off the ore.

In the large mines at Mineville not only are faults indicated by the relations of the ore, but at the western side of the Old Bed pit, the crushed and decomposed rock and slickensided faces can be seen over a width of about a foot. In the subsequent descriptions of the ore bodies these features will be again referred to.

The accurate and instructive exhibitions of faults which the mines reveal may with justice lead to the inference or at least the suspicion that faults are far more abundant than we have supposed, rather than that they are fewer. At all events increasing experience inclines us to a greater and greater faith in their existence. One is even justified in regarding each topographical depression as not only the possible but the probable location of one. The only other probable line of weakness in the Precambric areas is a bed of limestone.

Chapter 7

AREAL DISTRIBUTION OF THE SEVERAL FORMATIONS

Introduction. The delimitation of the areal geology involves great difficulties. The region has been heavily glaciated and in the higher altitudes drift is very abundant and serves to conceal the outcrops. Along Lake Champlain in the Paleozoic areas the Champlain clays mantle the surface and afford comparatively few ledges. The more mountainous districts are forested, and have been at least once and often several times cut over. The younger growth is thick and difficult to traverse. One might pass a ledge at a short distance without detecting it. But the most unsatisfactory features of all are involved in the nature of the ancient crystallines themselves. In the preceding descriptive pages their characteristic features have been set forth in as definite a way as possible in

[1] Tenth Census. 1885. 15:112–14. The 31.1 feet may be a misprint for 3.1 since Putnam states specifically that 13.5 is the greatest displacement observed.

order to establish reasonably sharp conceptions. In typical exposures all these are exhibited with all desirable clearness. Thus there is never any doubt about the crystalline limestones of the Grenville; and the associated schistose rocks, quartzites, and thinly foliated, rusty gneisses are almost equally easy to identify. Repeatedly some little exposure of the last named has attracted attention and has led to the later discovery of anticipated limestones. But as more massive gneisses are met the difficulties of drawing the lines of demarcation increase. No geologist can escape great uncertainty of mind in these regards. The writer has endeavored to set some of these fully and frankly forth in the subsequent discussion of the stratigraphic relations of the iron ores, and in the details of the Port Henry area of the Grenville. From long residence upon the metamorphosed sediments represented by the mica schists of Manhattan Island and familiarity thus acquired with undoubted rocks of this type on the one hand, as well as study of the Adirondacks and Highlands, as representatives of intrusive types, on the other, a disposition has been acquired to look for decided and fairly regular schistosity as an indication of sedimentary origin and in questionable cases, seeing that we are dealing with an undoubted plutonic district, the irresistible tendency is to place the massive gneisses of composition corresponding with intrusives, in the category of the eruptive rocks. Upon the map therefore in not a few cases the heavy massive gneisses have been put with the syenite series, with which also their mineralogy allies them, and with whose typical representations they are connected by imperceptible gradations. Yet it is quite conceivable that another observer might reach a quite different conclusion.

Another very troublesome difficulty arises in this further particular. From the typical representatives of the anorthosite, syenite and gabbro series, there are variations. Anorthosites in characteristic exposure contain little else than labradorite or some related plagioclase, and of this type there is no lack. But dark silicates appear in greater and greater amount; orthoclase does not entirely fail; and gneissoid structures are produced by the omnipresent crushing and shearing. In the end gneisses result, largely dark silicates, yet with augen or knots of blue labradorite still distinctly visible. Thus the Split Rock and Woolen Mill types result, both of which are intrusive in anorthosite. Yet the intermediate stages are well developed, especially along the outer border of the anorthosite mass and after much uncertainty as to the best course it was decided to color the basic anorthositic border as has

been done by Professor Cushing in the Long Lake sheet, and submit in the text the details of such intrusive relations as had been detected.

Again, if we start with the typical syenites of which there are good representatives, we find variations both toward the acidic and the basic extremes. Full details with analyses of these are given in the pages discussing the syenite series and under the ore bodies of Mineville, where the diamond drill has afforded exceptional facilities for study. The basic phases when sheared into gneisses afford rocks almost if not quite indistinguishable to the eye, from the basic phases of the anorthosites. Thin sections can not be prepared nor can microscopic determinations be made of every exposure. Indeed their importance and help can be easily overrated. Much uncertainty has been unavoidably felt. The writer can only state that after repeated study, he has chosen the coloring to the best of his ability. The acidic extreme on the other hand approaches both the granitic series and the possibilities of metamorphosed sediments.

Finally the basic gabbros have not escaped the general shearing and visibly pass into gneissoid phases in excellent exposures. They imitate almost if not quite indistinguishably basic phases of both syenites and anorthosites and contribute to the difficulties not alone of drawing boundaries, but of identification itself. Starting out from a typical and easily recognized exposure of massive gabbros, one may pass over dark gneisses, and hybrid types almost without limit, before another sharply identifiable ledge is met.

The lack of sharpness of characters has led the writer to look somewhat favorably upon the possibilities of infusion among the deep seated rocks. That is, a great plutonic mass may have absorbed into its border portions of so much of the older wall rock as to give an intermediate result neither one thing nor the other. While perhaps a difficult process to demonstrate, it nevertheless has its attractions and its reasonable side. If, for instance, anorthosites grow more basic at the borders, and if we have only fragments of an old limestone bearing Grenville series left, like islands at times in its midst, what more natural than that by absorption the bases of the old anorthosite magma have been increased to the point where pyroxenes and hornblendes become inevitable. An original magma, heated well above the bare requirements of fusion would, of course, be necessary to bring about this process, but there seems no insuperable objection to it at the heart of a great igneous center.

These introductory points having been stated, the areal geology may be passed briefly in review and notes may be recorded upon the more interesting features of each.

Distribution of the Grenville. The most extensive single area of the Grenville begins in the northern outskirts of Port Henry, and extends northward to and beyond the Cheever mine. The limestones are comparatively thick and are well exposed both by the railway cuts along the lake shore and in the quarries which have been opened for stock for the furnaces. North of Craig harbor and again north of Cheever dock the continuity is broken by intrusive masses of the syenite series which tongue into the limestone and which have probably contributed to its extreme metamorphism and its rich content of silicates.

This main area presumably extends westward under the heavy cover of drift near Moriah Center but is broken up by hills of syenite gneiss. Patches of the limestone and their associates appear, however, for as much as 4 miles west of Moriah. The last exposure is at the ophicalcite quarry on the old road to the Schroon valley and south of Broughton ledge. To the southwest and north, the Grenville is cut out by the syenitic gneisses. To the south around Bullpout pond at the headwaters of Grove brook another small area appears, and extends southward into the Paradox quadrangle where it widens out very much into a broad area along Penfield pond.

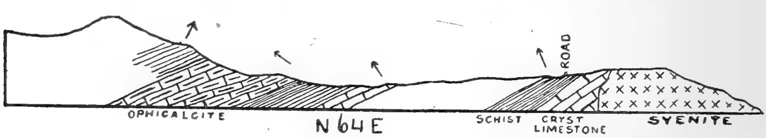


Fig. 15 Cross section of the Grenville strata at the Ophicalcite quarry, near Port Henry. The arrows indicate the strike in plan.

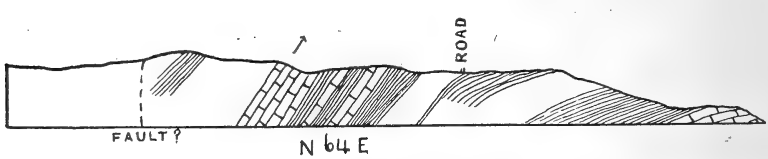


Fig. 16 Cross section of the Grenville strata 1 mile north of cross section represented in figure 15

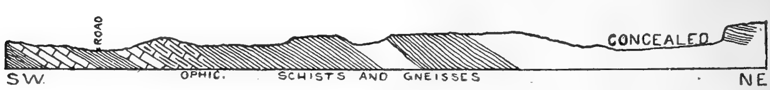


Fig. 17 Cross section of the Grenville strata 2 miles west of Moriah Corners

In the way of structures it is not easy to make anything out of these exposures beyond individual monoclines. The exposures of the large area along the lake dip at flat angles westward. The remote portions after the interval of drift, show easterly dips. A broad flat syncline is suggested but the evidence is too fragmentary to be unduly emphasized. Apparently a flat series of sediments was invaded by the eruptive rocks which sometimes as intrusive sheets, sometimes as batholiths of irregular shape and size, broke them up, partially absorbed them, contorted them and separated them into the patches which we see.

In the case of two separated portions of this principal area interesting relationships exist. Thus as one goes from the shores of Lake Champlain westward across the outcrop of the Cheever ore bed an exposure of gabbro and syenite gneiss is traversed with the ore in the syenite and about 150 feet below Grenville limestone. Ore, syenite and limestone make a westerly dipping half of a shallow syncline and are cut off as nearly as can be told by a fault, beneath a meadow at the foot of the ridge which culminates in Bald knob. The ridge is a coarse granitic gneiss believed to belong to the syenite series and its summit is 800 feet above the Cheever mine. Yet on the west side we find the green syenite gneiss containing the Pilfershire ore bed which dips westward in syenite beneath Grenville limestone just as at Cheever. Apparently the ridge is a fault block, on each side of which the Grenville has been dropped.

For one who favored the sedimentary origin of the gneiss, here interpreted as syenite, an argument is offered by these relations which is not without its force. Thus a band of syenitic gneiss lies just below the limestone, with which it has a rather sharp but fairly regular contact, where seen along the lake shore just north of Craig harbor. At this point the Crag (or Craig) ore bed was reported by Ebenezer Emmons. A mile and a half north but farther back from the lake the same relations are repeated at the Cheever ore bed. The same distance west of Cheever, the same relations prevail at Pilfershire. Thus there would seem to be a fairly definite horizon, with the ore at about this position in three separate cases, and sedimentary stratigraphy is strongly suggested. Yet from the mineralogy of the walls and their close similarity with the wall rock at Mineville, which in turn reproduces the characters of syenites, elsewhere undoubtedly eruptive, the Crag, the Cheever and Pilfershire wall rocks are believed to be intrusive sheets rather than conformable beds.

Nearly 5 miles north of the large area of the Grenville, and across a complicated mass of eruptive rocks is another exposure in the valley of Stacy brook. Limestones, black, hornblendic schists and thin gneisses make up a series of outcrops extending across the valley. The structure is a monocline, with intrusives, north and south.

One of the most extraordinary of all the exposures is a very narrow belt in Split Rock mountain, north of Westport. It lies along the old road that led into the quarry worked many years ago in the anorthosite. The belt appears but one or two hundred yards in width and has anorthosite all around it, but it contains typical, coarse, white marble, and associated schistose gneisses.

Again to the north, and in the edge of this quadrangle, the Grenville appears, not, it is true, with limestones but with characteristic gneisses. The limestones are present, however, on Split Rock point and island, in the Willsboro quadrangle, next north and these two constitute one connected area.

Immediately west of Westport station an area of basic, thinly schistose gneisses begins and extends a mile or more to the southwest. They have undoubted gabbro on the southeast and equally well defined anorthosite on the northwest. No limestones have appeared in them, and their characters are not altogether demonstrated as sedimentary, but it is the writer's conclusion that they can be best placed here.

The remaining exposures are nearly all near Elizabethtown village and are small in amount. A mile southeast of Elizabethtown there is an exposure of limestone with a little magnetite associated with it. It seems to be caught in a mass of anorthosite. It is called the Steele ore bed and is illustrated under the iron ores, later on [fig. 30].

Again a mile and a half north of Elizabethtown in the western foot of Woods hill is another small ledge, heavily charged with silicates and with anorthosites just above in the hill. Still more interesting are the exposures 3 to 4 miles northwest of Elizabethtown in the southern portion of Limekiln mountain, whose chief mass lies in the Ausable quadrangle. In the Westcott quarry where the rock has been taken out for lime there is a ledge with 25–30 feet of limestone, only moderately charged with silicates, among which is wollastonite. Gneisses presumably sedimentary succeed on the west up the hill, still farther westward and across a high ridge consisting of a phase of the anorthosite; in the next gulch, a little limestone appears but again to the west a fine exposure was

found, rolling over in a low anticline and dissolved out into small caves. Anorthosite was found higher up after an interval of sedimentary gneiss.

In very much the same way as depicted here, the Grenville is found in the Ausable quadrangle to the north; the Lake Placid to the northwest; the Mt Marcy to the west, and the Paradox lake to the south.

Collectively viewed one can not form any other broad and comprehensive conception of the areas, than that they once formed an extended and ancient formation which was invaded by the overwhelming amounts of igneous rock, in the deeper seated portions of a great center of eruptive activity. So extended are the masses of the latter that only fragments of the Grenville remain with slight suggestions of original structure. So far as these can be deciphered however, the dips are prevailingly moderate and the ancient sediments appear to have been folded or tilted to only a moderate degree.

Areal distribution of the granites and related types. The chief area of these rocks is in the southeastern corner of the sheet. They constitute the abrupt fault block of Bulwagga mountain, and extend westward from its escarpment for nearly 3 miles.

The more northerly exposures are relatively small, numbering but three in all and believed to be in the nature of dikes or bosses.

North of the east end of Crowfoot pond in the ridge a quarter of a mile from the water's edge there is also a development of granitic gneiss, but it is so closely involved with the syenitic series that it has been regarded as an extreme phase of these rocks and has not been colored differently.

At best these rocks are minor members in the local geology, and the uncertainties of their relations have been set forth in the general description.

Distribution of the anorthosites. The anorthosites make up the western third of the area and are the rock of the high mountains. They sweep around on the north and constitute the northeastern corner. This portion sends a prong southwestward nearly to Mineville and embraces in its sweep an area of the other formations, including the Stacy brook Grenville. The anorthosites extend into all the bordering quadrangles in New York, except the Ticonderoga on the south, where they fail entirely. From the Elizabethtown quadrangle they cross a few miles into the Paradox lake, but then cease and are, so far as known, seen no more in the extended Precambric area still farther south. They culminate in the Mt Marcy

quadrangle next west, where they constitute the lofty peaks in this center of elevation.

In their structural relations they can only be described as a huge batholith or irregular mass of vast size. Whether there were successive intrusions of the typical anorthosites or not, no evidence has been found. There is visible mineralogical variation in the greater or less amounts of the pyroxenic component, and in the development of biotite in the exposures east of Elizabethtown, but this does not necessarily imply separate intrusive masses.

Where the borders of the anorthosites follow a stream valley their outline is quite certainly conditioned by faulting, and we might infer enough displacement to produce decided discordance, but this relationship is rare, and the fault lines usually pay slight attention to formational borders.

Pronounced eruptive contacts have been observed in several instances. In the cascades of Slide brook and Coughlin brook which enter the upper Boquet river from the west are very instructive exposures. Another that is more accessible is in the Branch just below the junction of the Windsor hotel road and the main road between Elizabethtown and Keene. From the bridge at the junction for 200 yards or so down stream to and beyond the mill the brook flows over the contact of the anorthosite and the dioritic gabbro while a small basaltic dike passes from one rock to the other, with very interesting illustrations of the effects of cooling. The relations are shown in figure 4, which is based on a pacing survey.

Aside from these intrusive contacts it is soon learned that the border of the anorthosite mass is almost always more basic than the central portions. Harris hill, a marked elevation in western Moriah, is an exception, probably because it is a fault block, but elsewhere these relations almost always hold.

There are two small outliers of anorthosite, neither a perfectly typical case of the rock, but both referable to this series much more closely than to any other. One is a coarsely crystalline garnetiferous variety at the western end of Crowfoot pond, where it is well shown in the talus. The other is farther west along the old road which passes Crowfoot pond. Since both occur in the midst of areas regarded as belonging to the syenite series, and since the latter are believed to be later than the anorthosites, the two small areas must be surviving islands or huge inclusions.

Areal distribution of the Split Rock Falls type. The main area of this rock lies along the upper Boquet river above New Russia.

It extends a short distance to the northwest and has an eruptive contact with the anorthosite, fragments of which it incloses. Its contacts with the syenite near New pond are not sharply defined.

Areal distribution of the Woolen Mill type. The most accessible locality of this type is in the bed of the Branch, about a mile west of Elizabethtown but the same rock runs to the westward, where it appears in the rather few exposures along the brook itself. It also constitutes the marked ridge which lies between the two Grenville areas at the northern edge of the map. It forms the summit of Cobble hill, and appears well down its flanks. The blue knots or augen of labradorite occasionally appear and serve to identify it.

The same rock has a fine development in Blueberry mountain along the southern edge of the sheet, where once again the blue labradorite knots appear in the basic gneissoid rock.

Areal distribution of the New Pond type. This interesting rock is much less abundant than the others just mentioned. Only the exposure along the road to New pond has been discovered except for loose boulders to the south and except for possible gneisses derived from it by shearing.

Areal distribution of the syenites. The chief area of the syenitic series is in the southeastern portion of the area, but a few scattered exposures have been noted in outlying portions to the northwest, which although not sharply marked are believed to be intrusive in their nature.

The syenites are believed to constitute a batholith of size covering 50 square miles or more and of irregular outline. Its contacts with the other formations so far as worked out are chiefly faulted ones, syenite on one side of the valley, anorthosite or Grenville on the other. As to the distinction between possible basal gneisses in the Grenville and syenitic members dragged out into gneissoid forms, the matter is difficult. The syenites are believed to be the chief wall rocks of the iron ores.

Areal distribution of the basic gabbros. Within the area of the present map there are 25 to 30 known exposures of the basic gabbros, the greater number of which are small. They can rarely be identified as actual dikes. They must be usually mapped without definite or characteristic shape, either from limited exposures, or because the outcrop actually presents the form of an irregular boss or knob. The largest area covers 3 or 4 square miles and lies east of Little pond which is itself southeast of Elizabethtown. The gabbro mass contains several bodies of titaniferous magnetite. Two

interesting exposures appear in the cuts of the railway on the shores of Lake Champlain, one north of Craig harbor and the other north of Cheever dock. The actual exposures of definite gabbro are not of themselves extensive but their intimate association with dark hornblendic gneisses has given rise to the view that the latter were derived from the former. The possibility that the gneisses may be basic syenites, to whose mineralogy they are more closely related and that the gabbro may be intrusive in them has but recently been appreciated. It seems not unlikely that the hornblendic stringers, so prominent in the Grenville limestones, may be derived from the syenitic rocks rather than the basic gabbros.

Areal distribution of the basaltic dikes. The dikes are general in their distribution and no part of the area can be said to be more abundantly provided with them than is another. Our knowledge of their occurrence is rather a function of extended exposure or of artificial excavations such as mines, than of variations in distribution. Undoubtedly there are many more undiscovered.

The one controlling feature in their structural relationships is the development of lines of weakness and as the master lines run northeast and southwest, it is along these that the basaltic magma has chiefly broken through. The dikes have been observed cutting each of the more extended formations here described.

Dikes of the same type of rock as those here described are much more numerous to the north. Professor Cushing has found them in great numbers in Clinton county and so far as we can judge this area is probably over the focal source or was most accessible from it. These dikes are known as far south as Fort Ann, but they appear to decrease in number to the south.

Chapter 8

AREAL DISTRIBUTION AND GENERAL STRUCTURE OF THE PALEOZOIC FORMATIONS

The Paleozoic rocks outcrop on the New York side of the Port Henry sheet in three separate areas, the largest of which extends from Westport 7 miles to the south a little beyond Mullen brook. The second is a little longer than 2 miles forming the site of Port Henry, while the third constitutes the Crown Point peninsula. The latter is the northeastern continuation of the Crown Point area of sedimentary rocks of the Ticonderoga sheet. These areas appear as embayments in the eastern margin of the mass of the Adirondack crystalline rocks and owe their preservation mainly to their being

sunk in deeply between the overtowering mountains of harder Precambric rocks.

The physiography of the Precambric mass of the Adirondacks is, according to Professor Kemp's investigations, mainly controlled by block faulting with the structure lines running principally in northeastern direction. Likewise, the Plattsburg area of Paleozoics has been found by Professor Cushing and others to possess as the main factors of its structure a number of meridional faults with connecting cross faults.

The Port Henry and Westport areas are identical in structure with the larger northern Plattsburg area. They are both, in the main, sunken blocks bounded on the west by distinct fault scarps where the harder Precambric rocks project above the less resistant Paleozoic rocks. This fault scarp is easily recognized in a vertical cliff that crosses the northern part of the village of Port Henry; and it is still more prominent in the Westport embayment where for at least 6 miles it forms a bold escarpment separating the wooded Adirondack region from the fertile shore plain in front of it.

The fault contact can be observed in several places in both areas. At Port Henry it is well exposed on the north side of Lock Lane where it is seen to dip steeply (50°) to southeast, and still better under the bridge of North Main street over Mill brook at the northern outskirts of the village. Here the Grenville limestone comes in contact with the reddish Potsdam sandstone along a northeasterly striking fault, the sandstone being dragged up along the fault plane and representing the downthrow. While in the Westport embayment the contact is not directly shown, in several places, as at Mullen brook, in the Stevenson (Elm brook) farm and northeast of Westport village, the Beekmantown rocks are exposed a few rods from the high bluffs of Precambric rocks to the west, the steep local dip of the dolomite at the same time indicating the closeness of a line of profound disturbance.

These meridional faults emerge from the Precambric rocks in the south and disappear again in them to the north. The north and south boundaries of the Paleozoic areas are mainly formed by cross faults. In the Port Henry block which has a triangular form the master fault, forming the western leg of the triangle, runs in northeasterly direction and plunges into the lake in Craig harbor while the other leg is formed by a northwesterly fault, both intersecting near the first Y of the Mineville Railroad, where the Potsdam reaches its maximum altitude in this area. The latter fault

while not seen is clearly indicated by the presence of Potsdam sandstone in the cut of the Delaware and Hudson Railroad south of McKenzie creek, close to and below the topographically much higher Precambric rocks, as also by the much increased dip (10°) of the sandstone. One cross fault is directly exposed in the Port Henry block in McKenzie creek just below the highway bridge, a little east of the Y of the Mineville Railroad. This fault strikes n. 5° e. and separates a white Potsdam sandstone on the west from a more massive pink sandstone with distinct cross bedding. The latter represents the older bed and the downthrow seems to be to the west of the fault plane. Several smaller cross faults are well exposed to the north of the railroad tunnel north of the village. One of these (striking n. 60° w.) shows a drop of only 2 feet to the north, which, however, is finely shown by the shifting of a bed of black chert in the dolomite.

The Westport block is bordered on the south by a transverse fault, striking n. 50° e. whose fault inscarp (here Potsdam) is well exposed in the woods above the railroad track. In the railroad cut itself the Potsdam is seen abutting against the Precambric rocks. Another cross fault is to be inferred to again separate this Potsdam block from the Trenton beds adjoining to the north of it along the deep depression of the lower course of Mullen brook. Still another cross fault, running in northwestern direction, cuts off the Potsdam and Beekmantown rocks from the anorthosite at the northern outskirts of the village of Westport.

While thus the boundaries of these two Paleozoic areas that appear as embayments in the eastern Adirondacks are formed by faults, except in the east where the rocks dip under the waters of the lake, the physical character of the rocks and their relation to the underlying rocks bear intrinsic evidence of their formation in shallow water and not very far away from shore lines. This is especially true of the Potsdam sandstone, which forms but a thin veneer on an irregular surface in the southern part of the Port Henry area, so that in several places hillocks of Precambric rocks penetrate the sandstone beds.

In the Westport area the prevailing dip is to the west and south of west, showing that the fault block is tilted toward the master fault. At the base of the fault scarp the dips of the Beekmantown beds are steeply to the east, owing to the dragging. Low folds and cross faults cause locally divergent dips as at the mouth of Hammond brook at Westport and at several places on the shore south

of Westport. The small block of Potsdam sandstone at the south end of the area is tilted in northeastern direction.

The presence of outcrops of Beekmantown beds west of the Chazy, Black River and Trenton belts of this area, directly in the strike of the latter [*see* below] necessitates the assumption of a branch fault of the master fault striking toward northeast. This fault is quite likely to come out under and be a factor in the formation of the drift-filled shore between Westport and Cold Spring bay.

The Port Henry block is mainly tilted to the east and northeast; but clearly much broken by smaller faults. Along the railroad and near the shore the beds lie rather flat, near the western fault scarp they dip, however, steeply to the east and near the southern boundary they dip equally strongly south, but close to the fault scarp (as in the railroad cut south of Port Henry) they dip strongly north. The strong easterly dip along the western boundary and the north dip along the south boundary are obviously both due to dragging. These dips hence support the conclusion of the presence of the faults that intersect at nearly right angles near the Y of the Mineville Railroad, forming there the highest point of the tilted fault block.

That also the Beekmantown beds at the north end of the area which seem to rest in regular succession on the Potsdam beds are much fractured is well seen in the railroad cut where especially the black chert bands bring out distinct fault lines with the downthrow to the north and a throw of but a few feet. A larger fault appears to separate the divisions A and B of the Beekmantown. This is indicated by a depression between them and the different dips. With these numerous orogenic disturbances is quite clearly connected also the brecciated condition of much of the Beekmantown dolomite. The chert bands of the railroad cut furnish here again instructive examples. They are seen to be bent very irregularly and broken into angular fragments in other places, at one point the contorted band having doubled around the fragments. It is to be inferred that the brecciated beds slipped when still under the enormous weight of the overlying younger Paleozoic rocks and, were faulted, and thus a crush breccia formed.

The Crown Point area is in its entire structure a part of the Vermont plain, as already recognized by Hitchcock, Brainerd and Seely and indicated by the continuity of the strikes across the lake at Chimney point. The northeast strike and northwest dip bring up the Chazy, Black River and Trenton beds in succession

along the north shore, thus producing a most complete and accessible section. The eastern portion is separated by a fault, first recognized by Brainerd, and traceable into Vermont. Its downthrow is to the east and the throw about 100 feet. The greatly different levels of the formation and the opposite dips of the blocks furnish also fairly conclusive evidence that an important, probably meridional, fault passes under Bulwagga bay. The configuration of Bulwagga mountain points to the same inference.

Chapter 9

GLACIAL AND POSTGLACIAL GEOLOGY

From the close of the epoch of the Utica slate, until the oncoming of the great ice sheet of the glacial epoch, we have no records other than physiographic. This fact would lead to the inference that land conditions prevailed during at least a great part of the time. If any sedimentation took place, the beds were again removed by erosion which must have been of very extended character. The faults which have broken the Utica as well as all the older formations can only be described as coming at the close of Ordovicic time or in the subsequent interval. It is natural to connect them with the upheaval of the Green mountains which occurred at the close of this period, but they may have been long after. The evidence of a Cretaceous peneplain has been earlier mentioned and its possible faulting during the Tertiary, but the evidence must be admitted to be extremely vague. There is little doubt that at the time the great ice sheet invaded the country from the northeast as the scratches show, the relief was much as it is now. The ice plucked away the loose rock and freshened up the escarpments; it sculptured amphitheaters and cirques and gave to the rocky exposures much of the rugged character which they exhibit today. In the closing stages the deposits of drift and the later postglacial clays served to smooth over this roughness in the depressions and made the rocky, glaciated district tillable and habitable.

In the preglacial times, the land must have stood at a higher level with regard to the sea. Lake Champlain obviously lies in an old river valley, whose bottom is now at least 300 feet below tide or 400 feet below the present surface of the lake. This elevation of 300 feet and more is probably but a small fraction of what really took place, as we have long since learned from the various submarine channels, opposite our large rivers, and from the drowned fjords such as that of the Saguenay. At all events we are locally assured of more than 300 feet.

Again the surface must have been depressed in the postglacial or closing glacial times much below its present altitude. In no other way can we account for the deposition in such great thickness of the Champlain clays. Consisting as they do of fine sediment which required deep and quiet waters, they indicate a decided submergence. They reach altitudes of 200–300 feet above tide in Westport and indicate a downward journey to more than this extent. They must have been deposited in an arm of the sea, because of the marine shells which are found in them, more especially in the town of Essex, just north of the present area. A rather impressive up and down swing of the surface is thus demonstrated.

While the data upon the glacial deposits as here discussed have been gathered when attention was especially concentrated upon the hard geology and while more definite details could doubtless be accumulated by special work upon this branch, yet the following record is made that the material in hand may at least become available. For the latter history of the Champlain valley we have the careful studies of Prof. J. B. Woodworth and those of Mr C. E. Peet which are subsequently cited, and which have been drawn upon in discussing these topics.

The glacial and postglacial deposits will be reviewed under the following topics: moraines, boulders, scratches, clays and sands.

Moraines. Glacial deposits in the nature of ground moraine are, of course, general throughout the more elevated portions of the area. The drift to the east of New Russia is very heavy and in the gulch of the brook which enters the Boquet from the east it is well shown. In the valley of Roaring brook 1½ miles and more from the Boquet it is also markedly in evidence. Again to the south of Mineville and in the broad upland upon which are located Moriah Center and Moriah all the bed rock except that in the pronounced hills is concealed. In sinking the Harmony shafts at Mineville over 200 feet of boulders and clay were penetrated before the work grounded on the rock. Terminal moraines or glacial drift in marked lineal distribution can hardly be identified but rather it seems as if a broad valley was filled up, the loose materials being packed in the depressions.

One extraordinary exhibition of boulder clay may be seen in the banks of Grove brook in the southeastern corner of the map, and just east of the cross roads which are a mile and a half from Lake Champlain. The clay is thickly charged with pebbles up to 3 or 4 inches in diameter, which are almost exclusively from the Black River limestone of the Ordovicic. This limestone is not of great

areal spread in this region and its nearest ledges are on the northwestern corner of Crown point. The direction thus indicated falls in line with the scratches mentioned under the next topic but one, and is directly opposed to an outward and expiring movement of local glaciation to the northeast. The road which formerly existed parallel to Grove brook has been destroyed by a freshet.

Glacial boulders. Boulders of moderate size which have been brought in by the ice sheet are of almost universal distribution. They, however, are of special interest only when they are of some rock of sharply defined character and one contrasted with the ledges on which it may rest. The most striking of the boulders consist of Potsdam quartzite, an exceedingly hard rock, of a pale yellowish color. Even on the mountain tops these boulders appear, having undoubtedly been derived from the Paleozoic lowlands to the northeast. The remaining Paleozoic formations are rarely seen, but in this and adjacent quadrangles all have been noted except Utica slate.

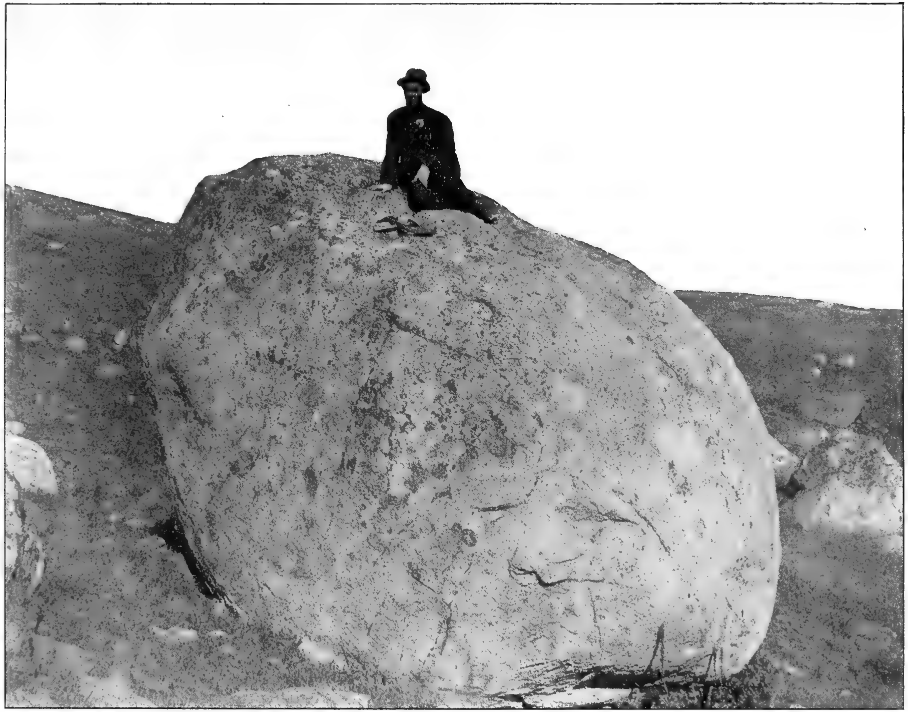
Anorthosite is a rock which is tough especially when crushed and recemented, and which lends itself readily to transportation. It is significant when found amid areas of contrasted formations. It is one of the most frequent boulders wherever there are anorthosite areas to the northeast. The syenitic and granitic gneisses are also common. A very few boulders of the crystalline limestone of the Grenville series and of the associated hornblendic schists have been observed but they are uncommon because of their poor resisting qualities and because of the relatively small areal distribution of the parent ledges.

A mile north of Port Henry and near the rose-quartz locality one small boulder of pink trachyte (or bostonite) was found. This rock occurs in several dikes in the Paleozoic strata at Essex and along the Vermont shore, especially on Shelburne point, but beyond a probable derivation from the northeast, its source can not be more sharply located.

As to the size of boulders the general range is from half a foot to 2 or 3 feet. Plate 12 illustrates one of fairly good size on the southern slope of Barton hill just below the ore bed. It is somewhat pear-shaped and is about 10 feet in diameter. The largest boulder noted, is in the woods, northwest of the Grenville area on Stacy brook. As paced off, it was 20 feet by 15 feet by 12 feet.

Glacial scratches. The scorings of the continental glacier which have been preserved are almost exclusively in the valleys and are best shown upon those surfaces of Beekmantown limestone which

Plate 12



Glacial boulder, 12 feet in diameter; pear-shaped. Barton hill, Mineville

have been covered until recently with clay and sand. On the exposed peaks and on the higher elevations where we would most desire to note the direction of ice movement, and where it was least influenced by the local configuration, the weathering of the surface has effectually destroyed the record. It may be therefore that the scratches remaining to us are the very last of the ice scorings and due to local glaciation. Nevertheless when they are all taken together throughout the region the testimony is the same. The direction is northeast and southwest and the ice invasion came from the northeast. This topic has been discussed by Dr I. H. Ogilvie in its general bearings.[1]

Back from the immediate shores of Lake Champlain, and in the area here mapped, glacial scratches have been noted in only two localities but as time goes by and observers are on the watch others will undoubtedly be detected. Just south of New Russia a rocky point projects into the highway from the west side and on it is a fountain. Upon this point the scratches are well shown and bear n. 52° e. true, or n. 62° e. magnetic. They run in this case parallel with the general course of the valley. In the extreme southeastern corner of the Elizabethtown quadrangle along the two northeast and southwest highways, scratches are well developed. The more northern instance runs n. 70° e. true or n. 80° e. magnetic and the southern one n. 65° e. or n. 75° e. magnetic. The local topography can have had slight influence in this case since the scratches are in a broad, open upland.

It is a striking fact that the ice sheet should apparently have moved against the hight of land, which it rode over. Dr Ogilvie reached the conclusion that the valleys were filled with stagnant ice, which bridged a passage for the great mass.

Clays and sands. Along the Lake Champlain shore the postglacial sediments are best developed in the Paleozoic flat south of Westport village and in Crown Point. The latter is so low, 140 feet as a maximum, that clays alone mantle it. Yet as noted by Dr C. P. Berkey, while in the field with the writer in 1908, the upper surface of the clay shows a curious downward slope from east to west, a relationship not easily explained by erosion. In the Westport flat the surface deposits reach the 300-foot contour but there is a marked accordance at 280 feet and several wave-cut ter-

[1] Glacial Phenomena in the Adirondacks and the Champlain Valley. Jour. Geol. 1902. 10:397–412.

races can be identified. They are relics of the postglacial Lake Vermont, the expanded predecessor of Lake Champlain as established by J. B. Woodworth[1] to whose work, and that of C. E. Peet, reference must be made for the interpretation of these phenomena as bearing on a wide area. The object, here in view, is rather to give to the reader a bird's-eye view of the region under discussion.

As to the thickness of the clays no very definite data has been obtained. Gulches cut them to a depth of 20 or 30 feet and the clays obviously go lower. In the Ticonderoga quadrangle on the south and in the northern portion of the town of the same name, brooks have eroded downward through fully 100 feet of clay. The depth is doubtless somewhat governed by the relief of the bed rock left on the retreat of the ice sheet.

Water-sorted sands are very much in evidence a mile or less west of Port Henry where Mill brook crosses the railway to Mineville. Very thick and extensive beds in the nature of delta sands have gathered from the 600 to below the 500 foot contour. They seem to have either been deposited against a lobe of ice which still filled the valley below, or else to mark a delta formed at a time when the waters stood at this level. The sands are deeply trenched by Mill brook and at periods of flood suffer severely. The present dam and pond used by the electric company have obliterated some of the exposures which were pronounced in former years.

Sands with more or less fine gravel appear in the Schroon valley and likewise in the valley of the Boquet river. The dunes of the latter have been mentioned in the opening pages as have also the deltas and lake bottoms. The correlation of the deltas would require more detailed study than has been given while working over the hard geology.

Chapter 10

ECONOMIC GEOLOGY

The chief of the mineral resources of the area here discussed is iron ore. Attendant upon the smelting of the products of the mines, limestone quarries have been opened in both the Grenville and the Beekmantown formations to supply the necessary flux. Some subordinate quarrying has also been done upon the serpentinous limestones of the Grenville for ornamental stone. There are besides these, great reserves of clay for the manufacture of brick

[1] Ancient Water Levels of the Champlain and Hudson Valley. N. Y. State Mus. Bul. 84. 1905. p. 190. *See also* the discussion by C. E. Peet. Jour. Geol. July-August 1904. p. 458.

should these ever be called for in the future. The several topics will now be described in order as follows:

1 Iron ores
- *a* Nontitaniferous magnetites
- *b* Titaniferous magnetites
- *c* Red hematite

2 Limestone
- *a* For flux, macadam etc.
- *b* For building and ornament

3 Clay

1 Iron ores

General commercial characters. The iron ores which are at present exploited are non-Bessemer and rather high in phosphorus. Magnetic concentration is employed to bring the phosphorus lower, and to a certain degree to raise the percentage in iron. Ores of Bessemer grade have been produced in the past and may any year be revived, since the deposits are far from exhaustion. Besides these two varieties, there is one other case of a magnetite rather rich in sulfur, an element which fails in the mines previously referred to. The ore was lean, however, and the mine, the Lee, near Port Henry, has been idle for years.

The titaniferous magnetites are a distinct and interesting type and are not at present of commercial importance within the area here covered, but they are not infrequent and are at least of great scientific interest. They are never as rich in iron as the similar ones farther west near Lake Sanford which are now about to be commercially mined and concentrated.

Red hematite has attracted attention in only one locality, just south of Port Henry, where it is the result of the decomposition of crushed hornblendic gneiss along a fault line. The pits have been abandoned and have been filled with water for years past.

The commercial importance of the iron ore deposits therefore hinges upon the nontitaniferous varieties, which are in some cases high in phosphorus, in others low. The predominant mining center is Mineville and from it the output really comes, but the revival of the Cheever mine north of Port Henry, with the aid of magnetic concentration has placed it again upon the list of producers, although the business depression of 1897-98 made the operation of the mill intermittent.

Geological associations. The largest mines occur in more or less gneissoid members of what is here described as the syenite

series, and the rocks are regarded by the writer as of igneous origin. The ore bodies must then be considered excessively basic segregations squeezed or drawn out into apparent beds. The largest of them exhibit a most extraordinary series of bulging folds and all are liable to rolls, pinches and forkings. Despite the igneous affinities of the wall rock the bedded shape of the ores has suggested to most observers a sedimentary origin so that this has been hitherto the most generally accepted view of them. The problem will be fully stated in the subsequent descriptions in association with which the points pro and con can be most significantly stated.

Several minor deposits are in granitic gneiss. Under this head belong the abandoned ore bed of the Essex Mining Company, south of Port Henry and the Lee in the outskirts of the village. One small occurrence, the Steele bed, just southeast of Elizabethtown, has Grenville limestone immediately over it. The cross section at the mine has been earlier mentioned when speaking of the distribution of the Grenville.

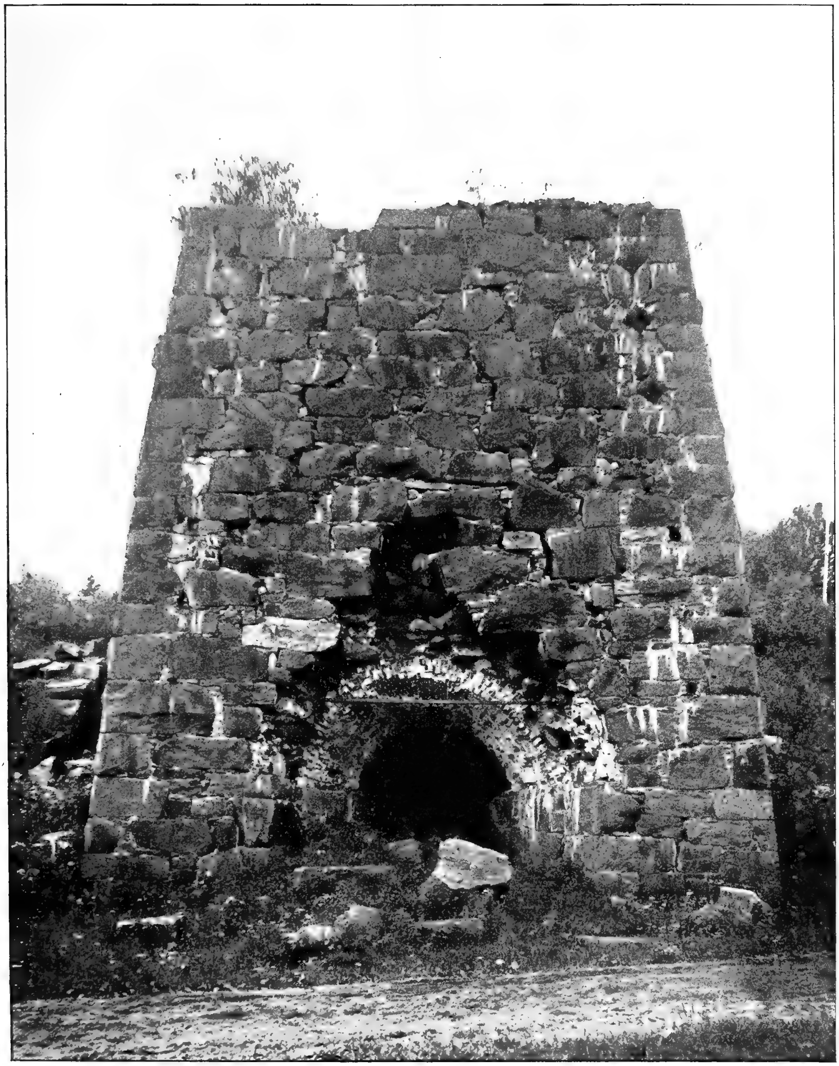
The titaniferous varieties are without exception in the basic gabbros. They form irregular masses, of indefinite shape and extension and of not very sharp definition against the walls. The ore is filled with the ordinary minerals of the rock and is merely a phase of the latter unusually rich in magnetite and ilmenite.

The mines and abandoned pits are all situated east of the great anorthosite exposures, and except for one or two outlying titaniferous bodies range along a belt which runs a little west of north from Port Henry, through Mineville to Elizabethtown. This arrangement does not appear to have any fundamental connection with any large geological feature and is doubtless fortuitous.

Historical outline of the iron industry

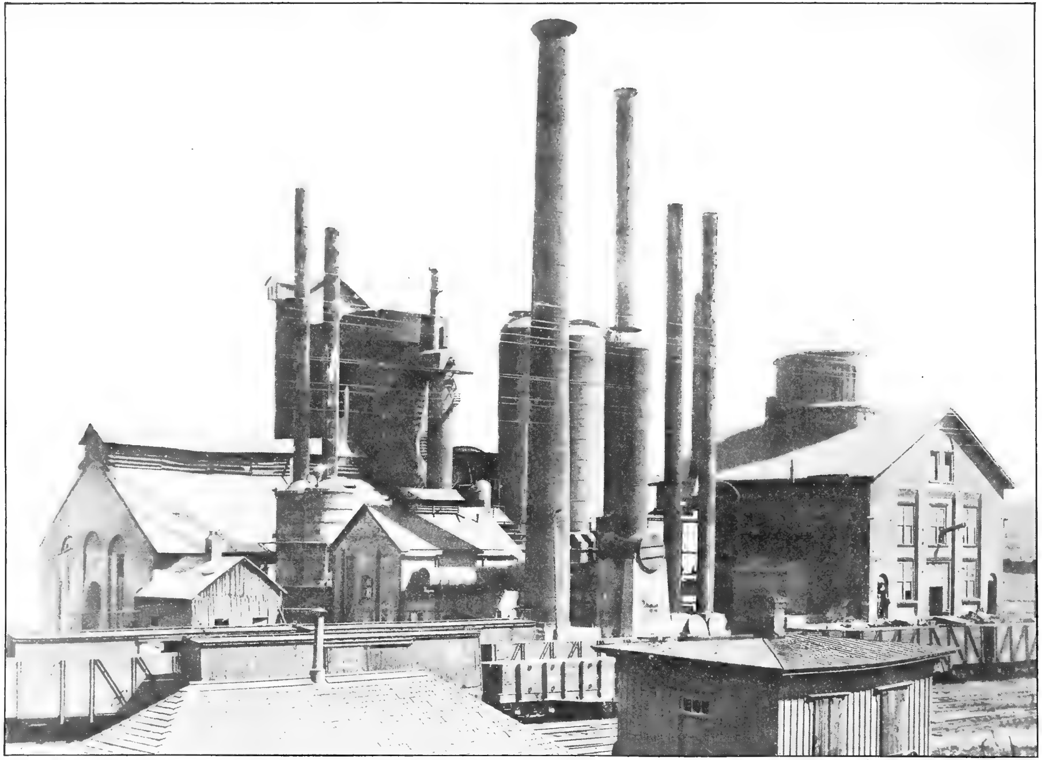
History. The first of the ore bodies to be discovered was the one which is now called the Cheever, but which when Professor Emmons was preparing his report, 1836–42, was known as the Walton or Old Crown Point vein [*see* Emmons's Report on the Second District, p. 237]. Nevertheless the name Cheever appears in Professor Beck's report on the Mineralogy of New York [p. 15]. The Cheever had been worked for 50 years when Professor Emmons visited it, and this would place its opening at 1785–90. The ore beds at Mineville were known in 1835–40, but the largest of them, as now revealed in the "21" mine (so named from the number of the old land lot) was first opened in 1846. It is evident that the

Plate 13



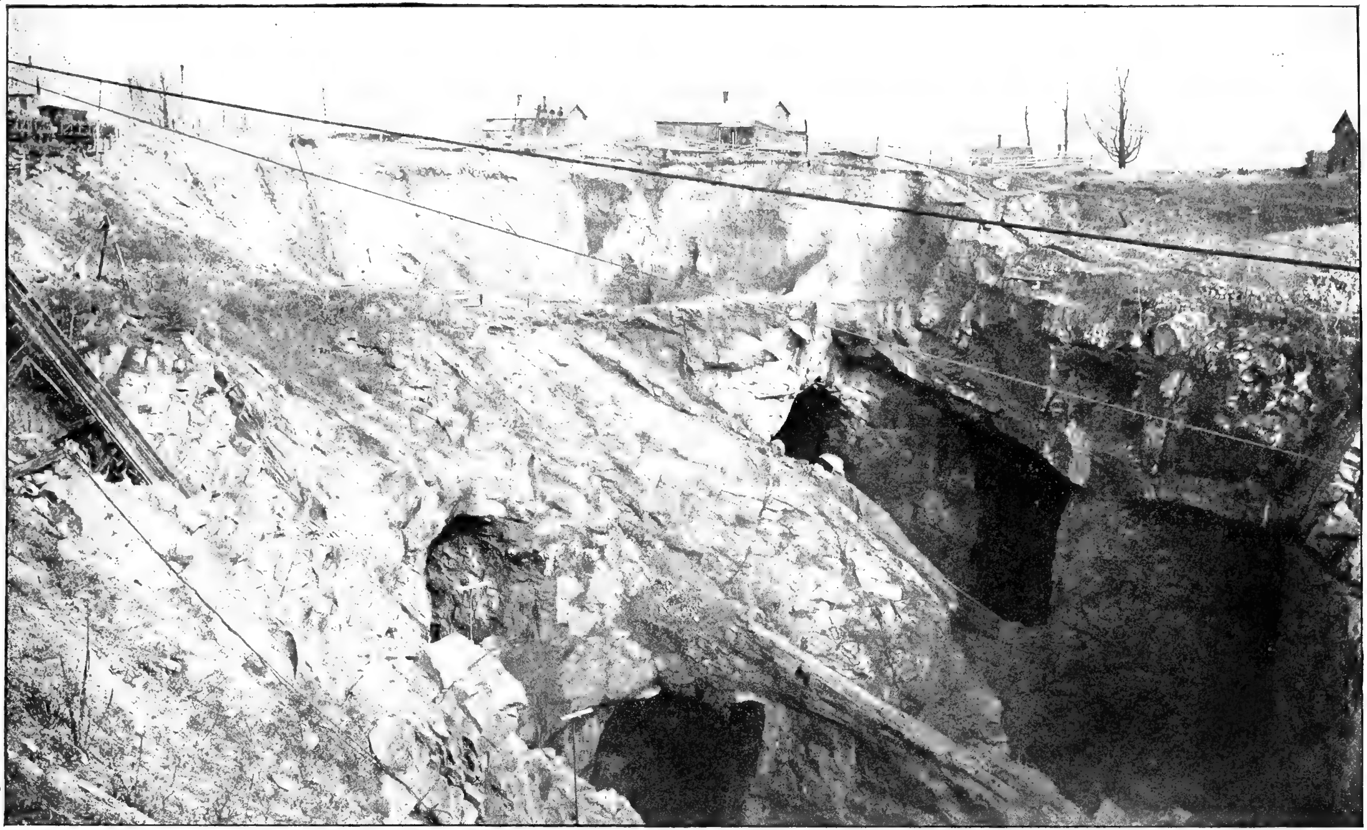
Colburn furnace, a charcoal stack built in 1848, about 1 mile west of Moriah Center, near Mineville

Plate 14



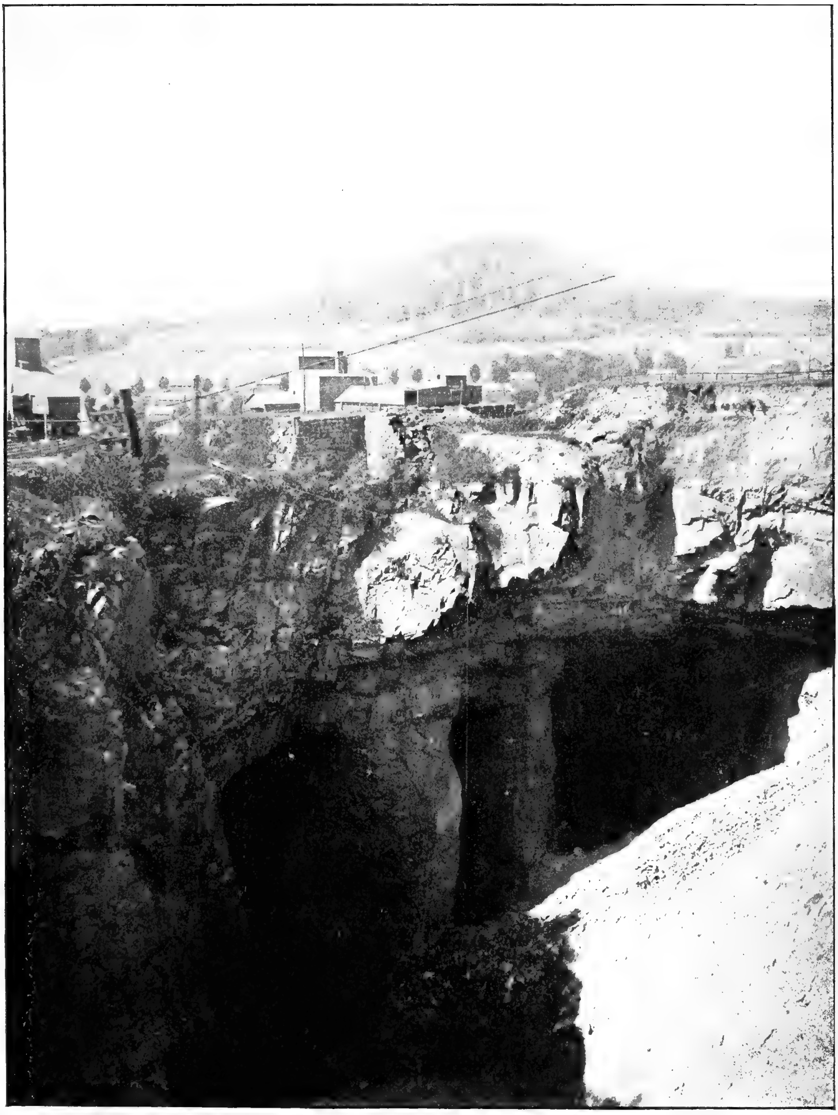
The Cedar Point furnace of the Northern Iron Co. Port Henry, 1908

Plate 15



Mine "21," Mineville, N Y. looking nearly east

Plate 16



Mine "21," Mineville, N. Y. looking southwest into the Tefft shaft chamber. Mt Tom is in the background.

early mining industry was prompted by the call for ore for the small blast furnaces which still remain in states of indifferent preservation. Plate 13 is from a photograph of the old Colburn furnace which was built in 1848, and which still stands about a mile west of Moriah Center. Another one is represented by a pile of collapsed masonry, at Fletcherville, also called "Seventy five" a mile and a half north of Mineville. At Port Henry there was a furnace at Cedar point, even in Professor Emmons's time, and this is the site of the large plant now in full blast. Twenty years ago there were two other blast furnaces called the Bay State, and situated just west of the steamboat dock. The abundant slag along the shore at this point came from them, but they have since been torn down.

The old bloomaries or forges were located where there was a water power sufficient to run the blast and the trip hammer. But for 25 years or so they have been extinct. In their day they consumed an appreciable fraction of the output of those mines which were low in phosphorus and sulfur. The ore was hauled many miles to them. By 1890, except perhaps at Standish, in Clinton county they had practically gone to the scrap pile.[1]

a Nontitaniferous magnetites

Following the map [pl. 17] the ore deposits will be briefly outlined in order from south to north.

No. 1. This pit now abandoned was opened by Butler and Gillette and continued under the name of the Essex Mining Co. The work was based upon a band of ore and is represented by an excavation 40 feet long and 8 to 10 feet high, sloping at an angle of about 60° and striking approximately n. 12° w. magnetic. The dump alone reveals a rather lean ore with much hornblende and feldspar intermingled. The walls are reddish granitic gneiss. No analyses of the ore are available nor were any samples taken or notes recorded by B. T. Putnam for the Tenth Census.

In the hill standing in the angle of the highways and northeast of Bullpout pond there is a belt of attraction running in a northeasterly direction. It has led to the opening of some small pits. Attraction apparently extends for a mile, since on the northeastern

[1] A detailed account of the old forges and of the process will be found in the following: Egleston, T. The American Bloomary Process for Making Iron Direct from the Ore. Am. Inst. Min. Eng. Trans. 1880. 8:515.

side of the neighboring 1453 foot hill another small opening has been made. At the latter, the ore lies at or near the contact of a dark basic syenitic gneiss below and a light acidic gneiss above, just as at Mineville. At the more southerly openings the rock is again basic syenitic gneiss. Between the two the geological relations are somewhat complicated. Pegmatites and granitic rocks occur, suggesting that intrusive granites are present, as indeed they are in evidence on the southeast.

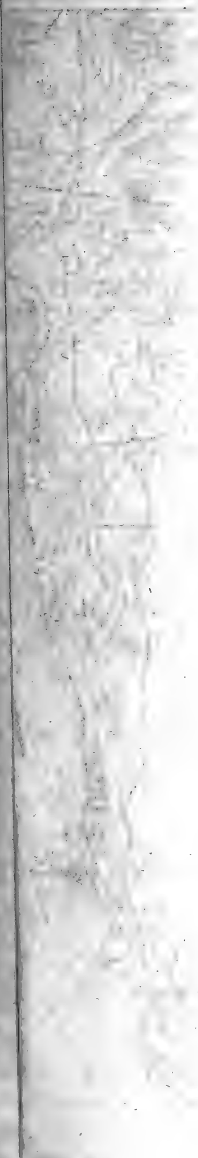
No. 2. Lee mine. This opening is just in the outskirts of Port Henry and in a little hillock with abrupt north and east sides which rise from a valley covered with sand. The nearest rocks both to the east and west are the Grenville limestones and their associates, but faults quite certainly intervene between them and the mine. Its wall rock is a granitic gneiss, whose dark silicate is biotite. It is reddish in color and somewhat different both in minerals and appearance from the greenish syenitic wall rocks, elsewhere met with the ores. The ore strikes n. 20° w. and dips about 19° westward into the hill at the more northern slope, but swings around to the southeast and steepens to a 30° dip on the south. B. T. Putnam visited it in 1880, for the Tenth Census [15:115], and has left a plan and sections. The mine is cut off on the north by a trap dike with an east and west strike. The dike can be traced across the hills to the eastward.

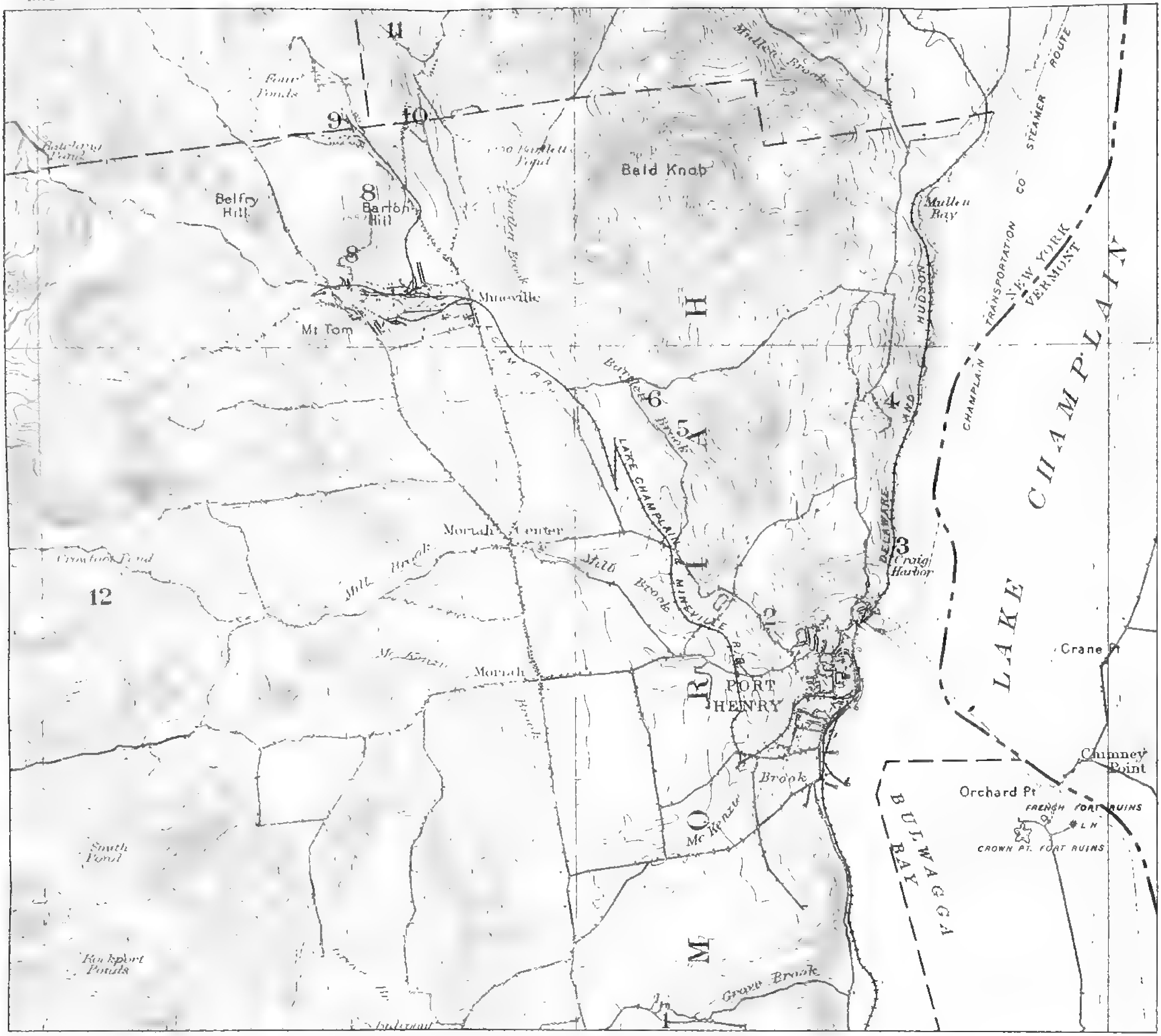
The pit is now full of water and serves as a dumping ground for refuse from the neighborhood. Putnam saw the mine when active and states that 9 feet of pyritous ore was displayed in the face. In old pillars a cross section can still be seen of lean, hornblendic ore. Putnam's analyses of samples from two lots, one of 2500 tons from the north slope, and one of 1500 from the south yielded the following. The sulfur, however, was for some reason not determined although it is the chief point of importance after the iron.

	1	2
Iron	45.01	44.38
Phosphorus	.047	.04

The ore is of low grade but the phosphorus is also low.

No. 3. Crag Harbor ore body. This is described by Ebenezer Emmons in the report on the Second District, page 236, as occurring in a cliff, 50 feet above the lake and half a mile below (north of) Port Henry and as being the most conveniently located of all the ore bodies in the region. It was 12 feet wide, in hornblende, and





PARTS OF PORT HENRY AND ELIZABETHTOWN QUADRANGLES

MAP OF PORT HENRY AND VICINITY

The location of the mines is indicated by numbers which are referred to in the text

dipped 35° west. The vein extended half a mile along the lake but the ore was pyritous, tough and difficult to crush for the forge. An analysis from Dr L. C. Beck's report on the Mineralogy of New York, pages 15 and 37, is as follows:

FeO	24.50
Fe_2O_3	66.80
$SiO_2.Al_2O_3$, etc	8.70
	100.00
Iron	65.23

This old deposit is no longer worked and has almost been forgotten. It occurs where the gabbros are a marked feature in the Delaware & Hudson Railroad cuts and it may be titaniferous. Since both Dr Beck and Professor Emmons speak of its difficulty of treatment the titanium may be the reason. Little was known of titanium in their time.

From Crag harbor for 3 miles northward the geological section along the lake shore is of more than ordinary interest. Partly from the original precipitous topography and partly from the cuts of the Delaware & Hudson Railroad, the exposures are excellent. The embayment of Crag harbor (called Craig on the U. S. Geol. Sur. maps) is due to block faulting, so that the northwest side is a precipitous wall. Above are the limestones and associated hornblendic schists and schistose gneisses of the Grenville. Below and with a sharp contact against the limestone is a massive hornblendic and feldspathic gneissoid rock in which are located the railway cuts. Immediately beneath the limestone is a band about 75 feet thick of a more feldspathic variety. Under the microscope it contains quartz and acidic plagioclase as the most abundant components. There is also a goodly proportion of orthoclase, often microperthitic and there are scattered shreds of brown hornblende. Below the last named and appearing in the railway cut is a more basic phase which consists, as the microscope shows, of plagioclase in broad crystals, orthoclase often microperthitic, a little quartz, rather abundant hypersthene and brown hornblende. It is a rock which could not have been derived from the basic gabbro. Its affinities seem to be quite close with the syenites. The dark green feldspar together with the abundant hornblende and hypersthene give the rock a basic look, beyond what the mineralogy of the slide would seem to warrant.

About 60 paces (or 6 rails) north along the track fine grained gabbro is found in the cliff, and at short intervals still farther

north rather coarse diabasic gabbro manifests itself. The contacts of the gabbro on the gneiss are not specially easy to decipher but they are believed to be those due to a succession of small block faults, which produce repeated exposures and which may readily lead the observer to infer the presence of more gabbro than is necessarily existent. The latter may well constitute only a relatively small dike or sheet.

In the first observations of this cut, and in several subsequent trips the writer gained the impression, not unnaturally, that a great intrusive mass of gabbro had entered through or beneath the Grenville series and that subsequent crushing and shearing had turned its southern and northern portions into gneissoid derivatives, leaving unsheared nuclei in the central parts;[1] but it is a better interpretation to infer an older intrusive sheet of syenite of acidic and basic bands, and refer to this the apophyses of hornblendic feldspathic rock which are so abundantly exhibited in the limestones and then to believe that later came the gabbro which was subsequently faulted in a way to give an undue impression of its amount.

The Crag Harbor ore then lies in the syenitic gneiss in almost the identical stratigraphic relations which are shown by the Cheever and the Pilfershire bodies.

One other possibility regarding the gabbro may be cited, which is one suggested by other very obscure relations which prevail between similar masses north of Cheever dock and on Barton hill, Mineville. It is that by the involution or infusion of a limestone mass the composition of the syenitic magma has been locally so enriched with lime as to attain the composition of a gabbro and to crystallize as such. On Barton hill it is almost if not quite impossible to detect the line where gabbro ends and basic syenite begins, and it is none too easy along the lake front, but while this explanation has been considered it has not been on the whole regarded with favor.

There is still a third hypothesis which falls in line with the views regarding the ores which have hitherto generally prevailed. It is, that the gneisses immediately beneath the limestone are not of igneous origin but are sediments in which the ores were deposited along with other sedimentary materials. The ore may have been magnetite sands, mechanically concentrated; or beds of brown

[1] Kemp, J. F. Gabbros on the Western Side of Lake Champlain. Geol. Soc. Am. Bul. 1894. 5: 213, especially p. 221.

hematite (bog ores); or beds of spathic ore; any one of which in the subsequent metamorphism yielded the magnetite lenses. There is much apparent reason for this view. Thus the ore bodies resemble beds; they are folded exactly as stratified rocks are; they run long distances; and in the case of the Crag harbor, the Cheever and the Pilfershire they are at what appears to be a definite stratigraphic horizon, in hornblendic gneiss, a few feet below Grenville limestone, and that too although they occur at intervals over a distance of 4 miles, and with a mountain ridge between two of them.

The writer does not fail to feel the force of this association, and the argument is a strong one. On the other hand the mineralogy of the wall rocks of the ore is that of the syenite series, unquestionably shown to be intrusive in other portions of the Adirondacks. The gneisses might be intrusive sheets. If they are, the apophyses of similar rocks in the limestones are readily explained. The ores might be basic segregations in an eruptive rock and as such they might readily be drawn out into apparent beds; they might then be folded like sedimentary rocks. It is a curious fact that they appear in three cases in the gneisses near, although not at their contacts with the overlying limestones. In other cases, as at Mineville, no limestones are known within a mile of the ore, and from one to two thousand feet of overlying gneiss have been shown by the drill and the exposures. The Cheever ore is, moreover, so much like the Old Bed ores at Mineville that one is disinclined to think of one origin for one, and a different one for the other.

In discussing the Mineville ore bodies these general topics will be again referred to.

No. 4. Cheever mine. This, the oldest opening in the region, is situated about 2 miles or less north of Port Henry, and at its eastern edge, outcrops rather more than a quarter of a mile from the lake shore and about 300 feet above it. The chief workings are just north of a small east and west depression, through which a little brook passes into Lake Champlain, falling over a fine ledge of Grenville limestone, one of the best exposures in the region. There is certainly a great fault between the limestone and the eastern edge of the ore, since north along the railway the limestone gives way to greatly brecciated gneisses. Farther north again gabbro appears, but in irregular exposures mingled with hornblendic gneisses and quite difficult to understand. The ore itself, however, outcrops as a marked band or bed in green syenitic gneisses, and runs to the north for nearly a mile, with occasional

pits. The Cheever at the southern end is, however, the chief one. These workings, now being revived after years of idleness, dip down steeply, at 50° or 60°, then flatten at somewhat over 200 feet vertically from the surface and run westward until cut off by a fault. Their relations are shown on the accompanying section reproduced and reduced from the bulletin of the Geological Society of America 1894, volume 6, page 251. The only point of revision lies in the fact that our recent fuller knowledge of the basic syenite gneisses, makes the occurrence of unbroken gabbro

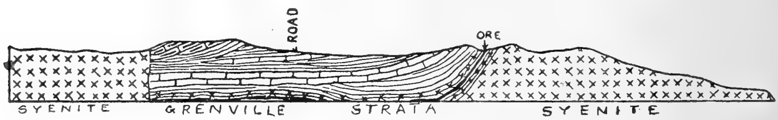


Fig. 18 Cross section at the Cheever mine, in a direction n. 60° e.

on the east doubtful. Field observations the past summer led to the conclusion that much of the black hornblendic gneiss, formerly taken for gabbro, is basic syenite gneiss, but massive gabbro does occur mingled with it. The ore is a band in the syenitic gneiss, here quite quartzose, and about 150 feet from the undoubted Grenville. Below the ore 50 feet of similar gneiss appears before the basic rocks take its place. As the ore bed is followed north the dip appears to flatten and in an old working about half a mile from the Cheever slopes, the strike is north and south and the dip 20° west. The same wall rocks, however, appear.

Another outcrop of ore appears along the present highway a quarter of a mile north of the old Cheever engine house. It strikes northeast and dips southeast. It has limestone not over 15 feet above it and while thus apparently stratigraphically higher or nearer the limestone than the position of the western end of the Cheever, if we consider it the same bed, it suggests a synclinal basin for the ore, with a pitch of the fold to the south. There can be no doubt that a north and south fault on the west beneath a meadow cuts off both the ore and the Grenville series in this direction.

The Cheever ore resembles very closely the Old Bed variety at Mineville. It is not quite so rich in phosphorus, but is still rather high in this element. Mr Putnam for the Tenth Census [15 : 114] took six samples, four underground and two from stock piles on the surface, which showed the following percentages:

Iron	65.33	63.5	63.86	64.42	64.77	63.08
Phosphorus	0.643	0.603	0.689	0.452	0.673	0.573

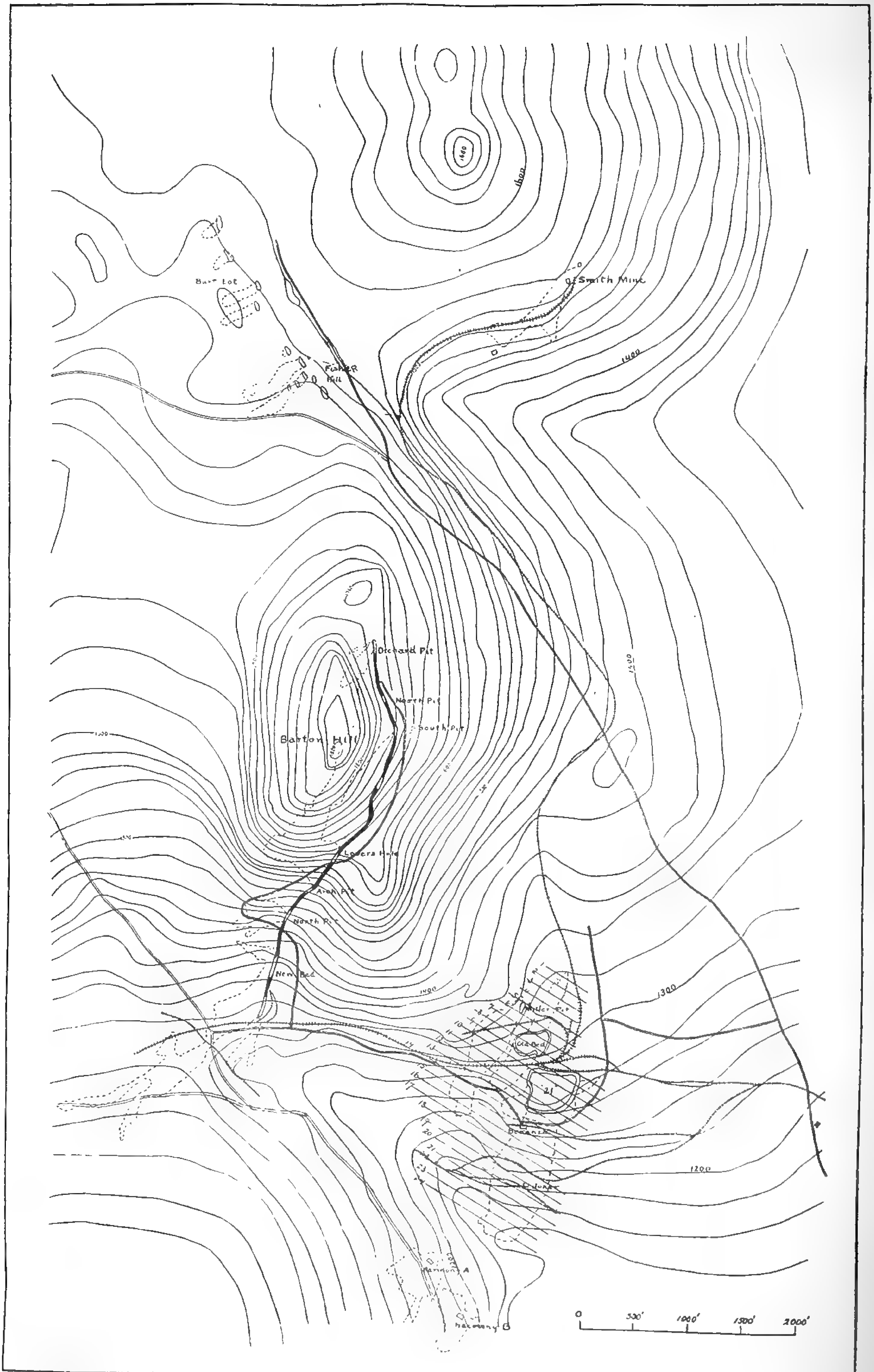


Fig 19 Map of the vicinity of Mineville, to show the location and relations of the Old Bed, Barton Hill, Fisher Hill and Smith Mine groups. The parallel numbered lines refer to the sections, figures 20–27.

Titanic acid was found in five of the six, but its amount is very small. The ore is rich and, as shown by the analyses is of quite remarkable uniformity. In 1907 a magnetic mill has been built and concentration of the leaner unused ore has been undertaken accompanied by a reduction of the phosphorus.

Nos. 5 and 6. These two pits are called the Pilfershire. They lie at the western foot of the ridge which intervenes between Moriah Center and the lake. Not far above them is the Grenville with its limestones, and the relations are extraordinarily like those at Cheever. Even the gabbro appears not far to the eastward as detected by F. L. Nason, who has called the writer's attention to it.

The southern pit is a small one and of no apparent importance. The northern pits consist of three larger and two smaller openings. They strike nearly north and south and dip 60° west, passing below the highway 50 feet lower down. The wall rock is the familiar green gneiss which in thin section shows plagioclase and pyroxene. The mines are now abandoned and full of water.

The close parallelism between the geological relations here displayed and those at the Cheever is worthy of emphasis. In both the ore belt strikes nearly north and south and dips at about 60° west. It is in the characteristic green gneiss of almost identical mineralogy. Just above are the Grenville limestones. Just below but after an interval of gneiss is the gabbro. Between the two stands a ridge of old syenitic gneisses, with no Grenville involved and extending 2 miles without a break. Undoubtedly faulted upward, they make a mountain summit, 500 feet above the Pilfershire and 1000 feet above the Cheever.

Nos. 7 through 11. Mineville group.[1] A general outline of the relations of the ore bodies at and near Mineville, may first be given. There is one group of mines based on a large faulted and folded ore body in the village of Mineville itself. It outcrops at about the 1200 and 1300 foot contours and is the basis of several distinct mines, some of which are no longer worked. A half mile to the northwest Barton hill rises to an altitude of 1880 feet and on its eastern slope, and ranging from its 1300 contour to the 1750 is a long diagonal outcrop with many pits. The group, collectively

[1] In the preparation of these notes, every possible kindness has been extended to the writer by Mr S. Norton, general manager of Witherbee, Sherman & Co., Mr S. LeFevre, chief engineer, and Mr Rogers Hunt, assistant engineer. Mr Guy C. Stoltz, engineer for the Port Henry Co., has been equally courteous and helpful in affording data and advice regarding the adjacent properties.

taken, is here called the Barton hill. It is possible that this bed swings around to the east under the drift and is the basis of the two Harmony shafts, south of the Mineville groups [*see* map: fig. 19]. Yet there is still much uncertainty about this connection.

At the north end of the Barton Hill group a gap of concealed and drift-covered fields intervenes with no demonstrated ores. After half a mile, ore again appears in two bands one over the other, at the openings called the Fisher hill and Burt lot, both on the 1600–40 foot contours and now for 10 years or so idle.

A half mile east of Fisher hill and on the 1450 contour of another hill, is the recently revived Smith mine, whose ore body is tapped still lower down by the O'Neill shaft. Another interval ensues to the north and then after half a mile two old-time but long abandoned mines are met, called the Hall and the Sherman. The former is one of the oldest in this locality and is mentioned by Professor Emmons. Drilling has recently been in progress in exploring them, but no mining has been done for many years. Still farther north no ores are known for several miles.

Mineville group. These great ore bodies are the chief source of the local production, and they present a mass of noble proportions. Thanks to the liberal spirit and courtesy of the two companies, and to the excellent and careful records of the engineers they can be so well illustrated that with the solitary exception of the Tilly Foster mine in Putnam county, they give us the best idea of the general shape and relations of a magnetite body yet afforded in this country. At the latter the structural relations are simpler, and the amount of ore much less. The Mineville group presents a very violent case of folding, accompanied by stretching and pinching of the crest. The ores are in a pitching fold which makes depth rapidly to the southwest, so that we have to keep the relations constantly in mind in terms of solid or three-dimensional geometry. At the north end we have further to deal with a series of faults and a very puzzling relationship, which on the basis of one bed of ore is not easy to satisfactorily clear up. In the present description, the writer's paper and sections prepared in 1897 and published in the Transactions of the American Institute of Mining Engineers, volume 27, pages 146–204, are brought up to date and are made to include the results of 10 years of mining.

There are three principal and separate faulted parts of one great bed, viz: roughly from north to south, the Miller, the Old Bed or Mine 23 (the first discovered under the name of the Sanford pit) and the "21"-Bonanza-Joker continuous ore body, the chief

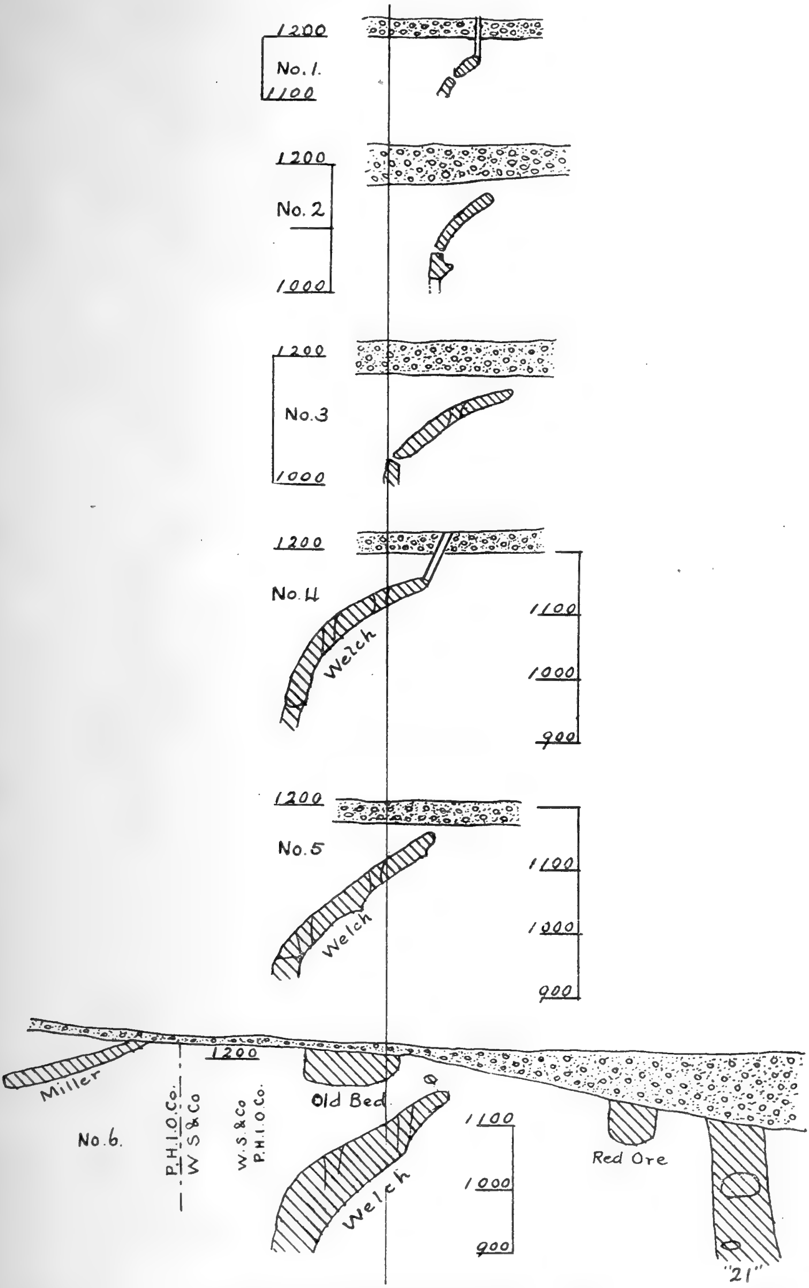


Fig. 20 Sections 1 to 6 of the Old Bed ore bodies, Mineville. Sections are 100 feet apart and drawn with the same vertical and horizontal scales. *See* figure 19

source of the ore. There are several shafts for Old Bed and "21" (named from the lot) and there are large open pits as well. The axis of the fold strikes about n. 30° e. true, and, as stated, pitches south. The full extent to the south has not yet been revealed. The sections here used are 24 in number, separated by intervals of 100 feet, so that they cover 2300 feet. The folded bed is broken by two main faults with strike a little more northerly than the axis of the fold, and apparently by one east and west fault under the skip way of mine "21." At least two trap dikes are known, running parallel with the main faults and probably themselves following additional small fault lines, while one other dike crosses the Joker at its southerly end in a nearly east and west direction. In the Harmony mines, the apparent prolongations of the north and south dikes are revealed. If now the reader follows the description with the diagrams beginning on the south with No. 24, the relationships can be most intelligibly stated [figs. 20–27].

Section 24 is largely inferential, but it is probably not far from the truth. The ore is a steep, vertical anticline, of which we know little except at the crest. In No. 23, which is more fully based on mining experience, a swell has developed in the eastern limb, and the two limbs have come together in depth. The drill has revealed a second and lower bed. In No. 22 the swell is still pronounced in the east limb, and a curious shoulder with an almost flat top has been revealed in mining. The lower bed continues as in the last section. In No. 21 the swell contracts somewhat, but the bulge toward the upper left-hand begins to assert itself, which is thereafter so marked a feature, and is apparently due to the stretching of a wellnigh viscous mass under irresistible compression, if indeed the rock was not still liquid from an original molten state. In No. 20 this upper left-hand bulge is much more pronounced, while the eastern shoulder is still very much in evidence. The intervening horse of rock has widened appreciably. In section 19 the upper western bulge has thinned somewhat, and has a very flat top, while the eastern shoulder has narrowed. It is very near the point where the Joker shaft first grounded in the ore. In No. 18 the upper western bulge has shrunk still more and the lower eastern shoulder has almost disappeared. Deeper mining has shown the true relations lower down on the limbs. We find them pinched together, so as to entirely circumscribe the horse of rock. In No. 18 also the sections first intersect the Miller pit as a small end of what soon

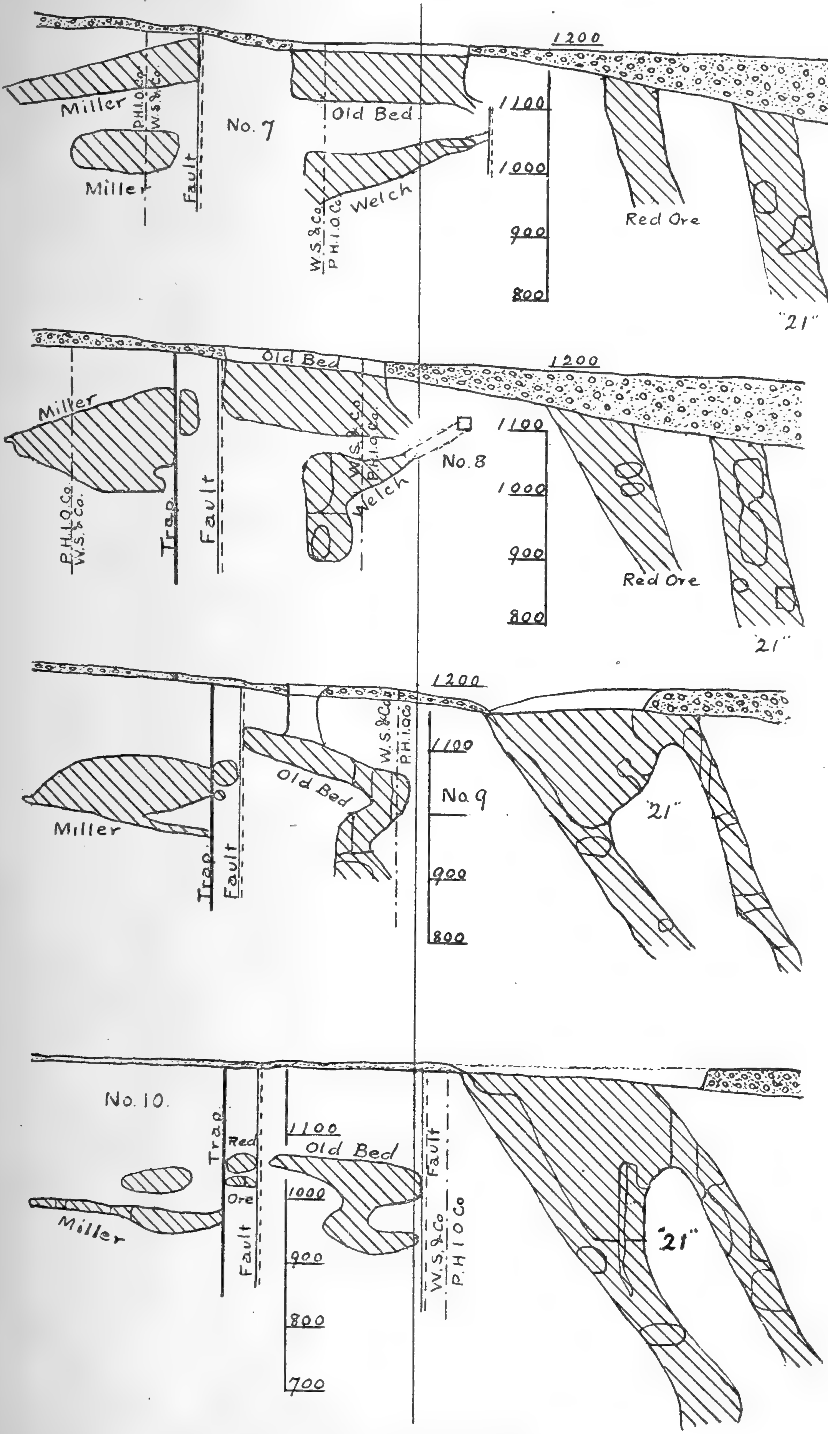


Fig 21 Sections 7 to 10 of Old Bed ore bodies, Mineville. *See* figure 19

becomes a large ore body. This can best be followed up by itself. In No. 17 the limbs have parted again, so far as yet indicated and the horse of rock has widened. The upper left-hand bulge has drawn in a little more. In No. 16 there is a bulge in the western limb, low down, but no very marked change in the other parts. In No. 18 we first encounter the property line and as developments have not been extensively made on the east side the data are not yet available. It is not an unreasonable expectation that the bulge in the lower right-hand limb of the earlier sections should manifest itself in depth to some extent in the as yet undeveloped portions to the north.

In No. 15 there is little change, but additional data as gained in the future will be of great interest. Between 15 and 14, a very remarkable change takes place. Apparently by a pinch and thrust from southeast to northwest a great bulge or wrinkle was rolled up on top of the anticline hitherto described, and just above its horse or core of rock. The old anticline soon pinches out but the new wrinkle bulges into a great second shoulder or roll, higher up than the one which we have hitherto followed. The latter gradually diminishes and in the end practically disappears between Nos. 12 and 11. Meantime the increasing bulge of the new wrinkle makes the noble ore body which was opened up originally in the Tefft shaft and in the great open cut of the "21" pit. The central horse of rock itself turns up to the vertical and, in the No. 13, even rolls over beyond it. All these features appear in sections 14 through 11. The upward trend or pitch of the axis of the fold now asserts itself strongly, and in Nos. 10 and 9 we see it almost reach the surface. Between 9 and 8 it emerges and thereafter the ore is in two separate limbs which run through No. 6. Beyond this point they have not been much mined in recent years, but, leaving faults out of consideration, we should expect the ore to be terminated only by the upward rise of the original outer or eastern edge of the great sheet of magnetite. This edge has been nowhere reached as yet in the deeper mining of the southern sections. It constitutes one of the interesting questions for the future to develop. As to the course of the western limb, when prolonged beyond the workings as yet opened up, it is probably faulted upward in the Old Bed-Welch ore bodies. That is, it probably flattens, encounters the fault shown in sections 13 and 14, is thrown upward and constitutes the Old Bed-Welch ore body with all the convolutions of the latter. If we turn to section 10 in which Old Bed was followed up to the fault line, at about the level of 940 feet, we can see that in order to allow

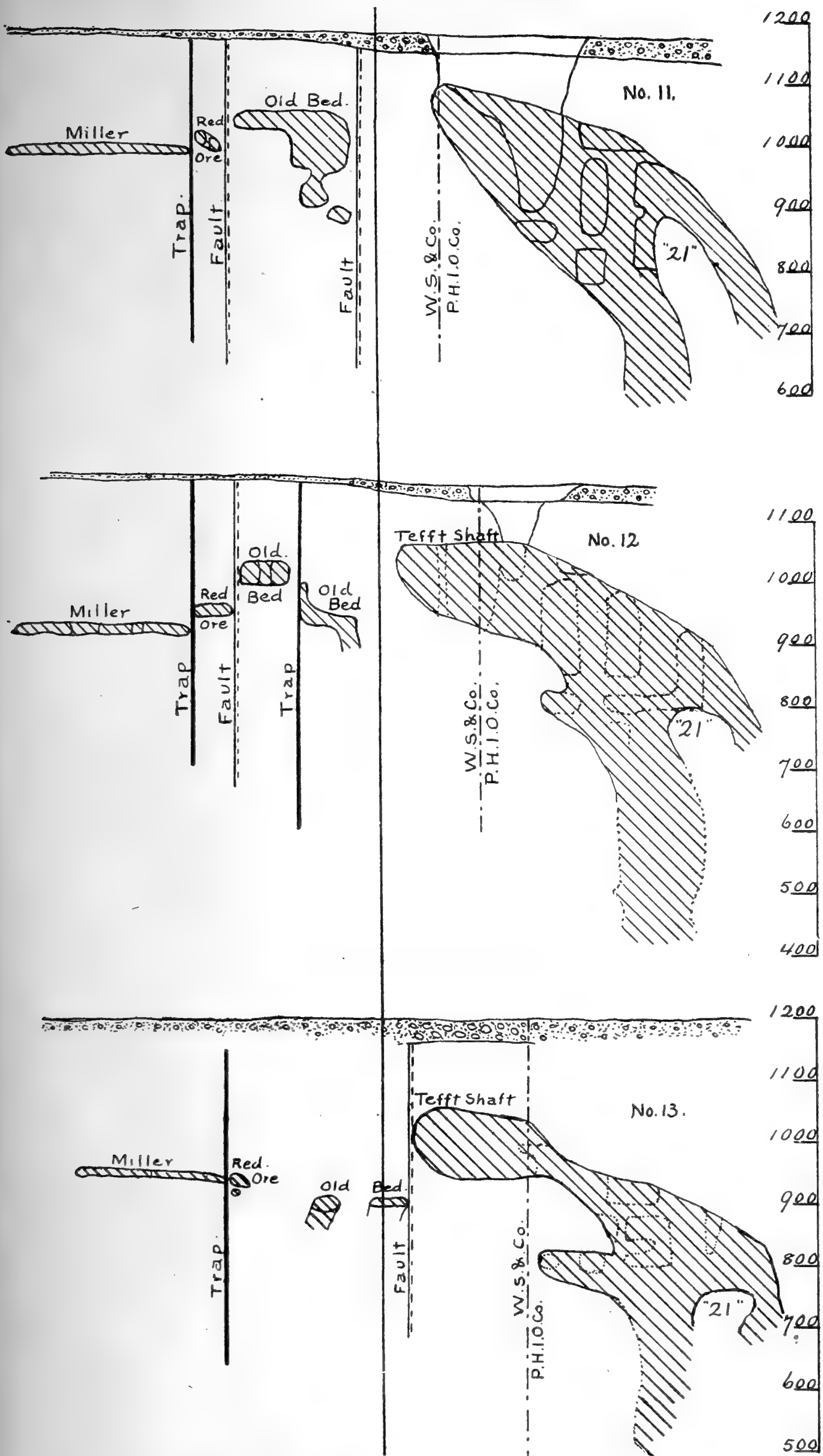


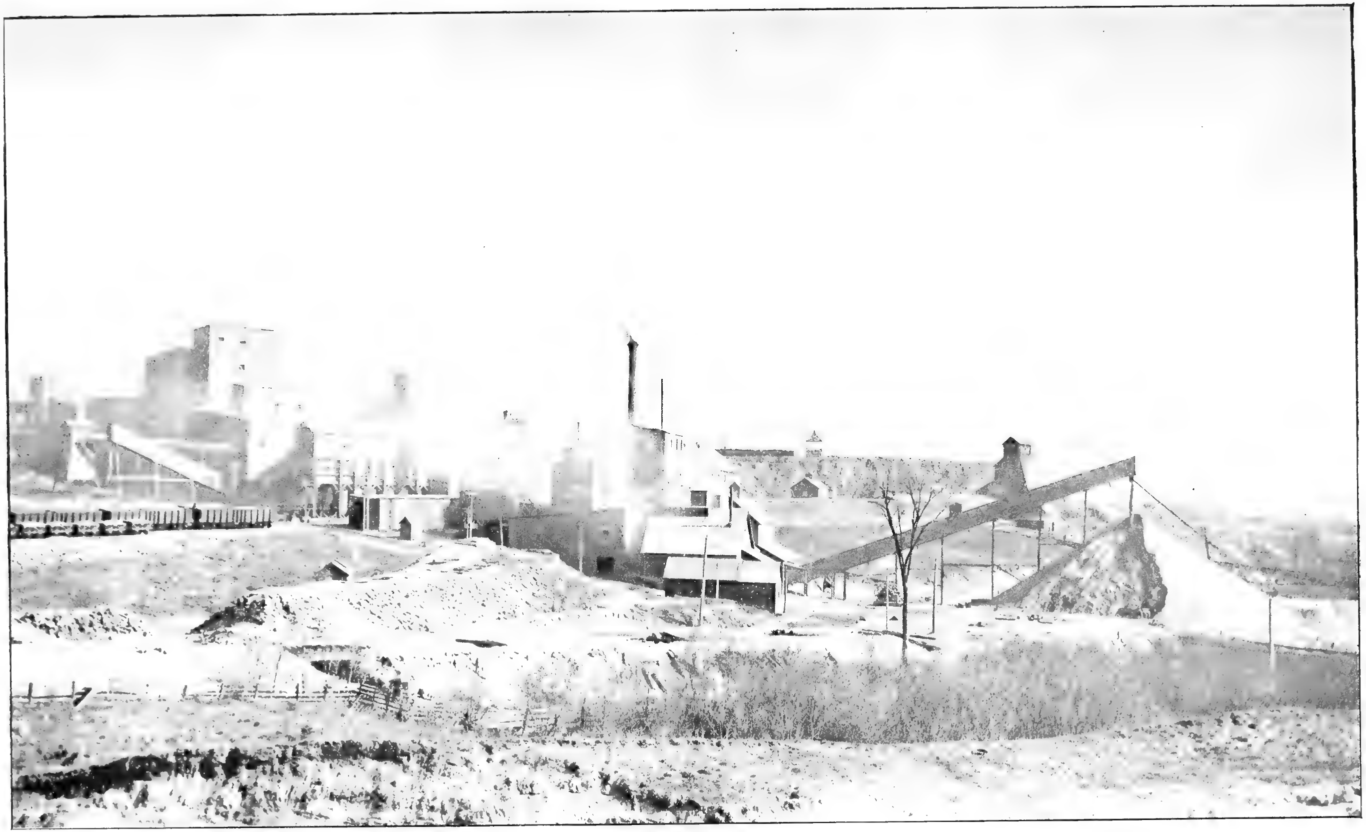
Fig. 22 Sections 11 to 13 of Old Bed ore bodies, Mineville. *See figure 19*

the western limb of "21" to flatten and come over to the fault, there must be a displacement of at least 300 feet. If the western limb of "21" rolls upward to the fault this throw will be diminished. We must not assume a purely vertical throw, since increasing experience brings home to us the conviction that almost always faults involve a diagonal shift along the fault plane.

Assuming therefore that Old Bed and Welch are the same ore body and are the faulted representative of the western limb of "21," an assumption which is corroborated by the similarity of the ores, we may follow out the curious convolutions presented by them. In sections 14 and 15 they are very indefinite and are mostly known by drill cores. The stray ore body shown in No. 15, on the center line, was revealed by a drill hole. Its identity is not known. The other one in No. 14, east of the fault and 200 feet below the Tefft shaft is also of uncertain relationship. Old Bed is first recognizable in this section, although little is accurately known about it. The ore grew small as followed many years ago and the workings were abandoned. In No. 13 Old Bed was found double, but again was not extensively opened. We know little about it. In No. 12 it develops a steplike roll of its own and is cut into two parts, by the small fault into which the trap dike has forced its way. At No. 11 the dike has pinched out and the fault was not noted. The ore is anvil-shaped and curiously pinched below. In No. 10 it is a reversed S-shaped fold and the core of rocks begins to manifest itself on the west, which is of great importance in the next sections. It is similar to those in the Joker-Bonanza "21" fold, but dips west instead of east. It rises toward the surface and ultimately cuts off Old Bed proper, from its downward prolongation, the Welch bed, until finally beyond No. 6, Old Bed runs out into the air and is lost. Meantime the Welch limb runs along and rises, with a lima bean pod cross section until it too goes into the air. Within the last year or two a new shaft has been sunk to tap the Welch ore on the line of section No. 1, so that we now know that this ore continues downward lower than was formerly shown. More recent data also show that in No. 7, rock cuts off the ore on the east, apparently before the upward curve of the ore was found and a fault is suggested.

In its western prolongation as shown in sections 8–12, Old Bed encounters faults and an area of broken ground with one or two disconnected masses of iron-stained, apatite-bearing ore called "Red Ore." The red color is due to the crush and to the consequent alteration of some of the minerals. In the slides the color

Plate 18



The mills at Mineville, N. Y. looking northeast. The Joker shaft is on the right; the Bonanza shaft on the left.

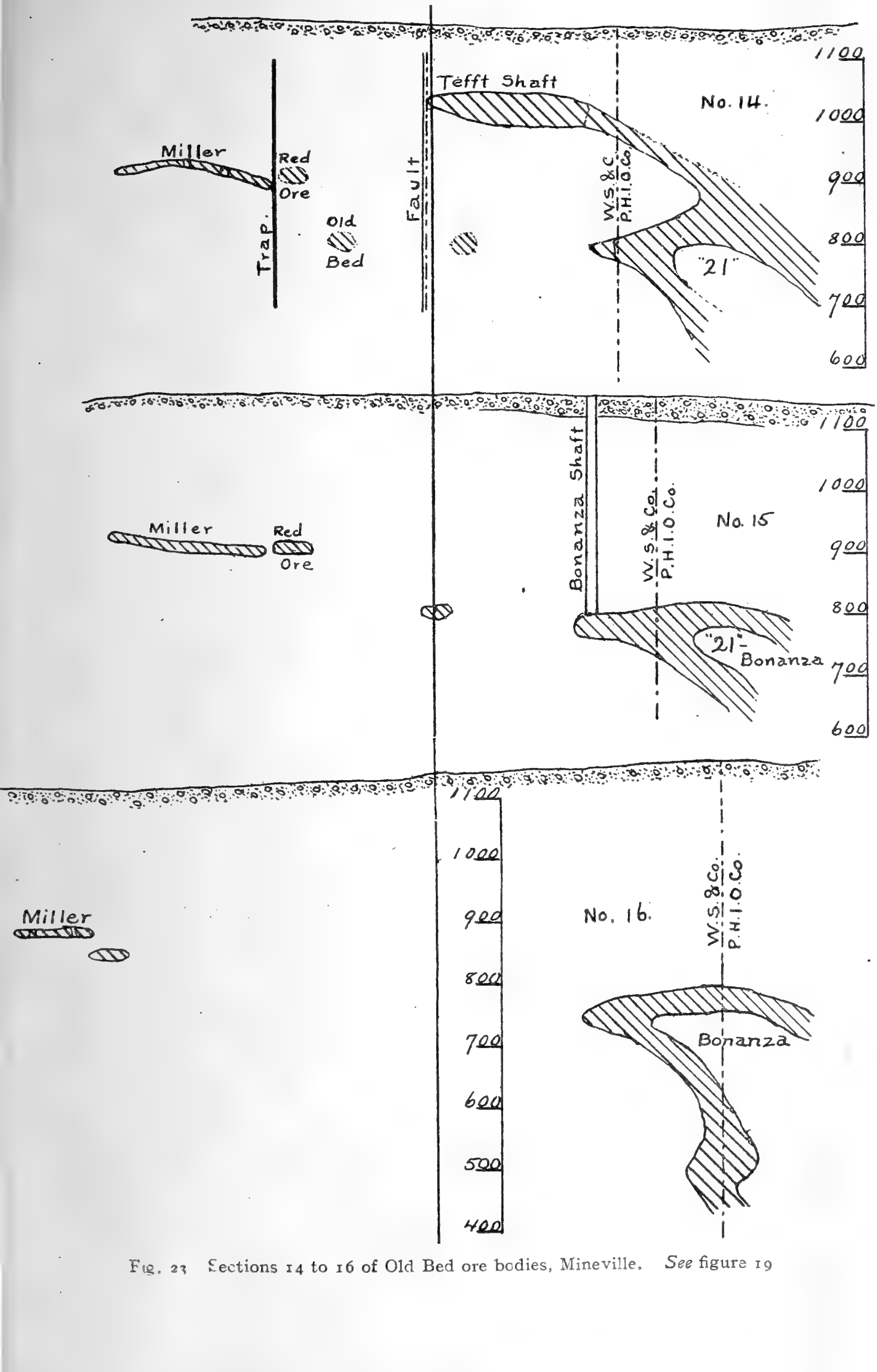


Fig. 23 Sections 14 to 16 of Old Bed ore bodies, Mineville. *See figure 19*

is clearly shown to be caused by red hematite infiltrations into cracks. The source of the iron oxid is without doubt decomposed pyroxene crystals.

Beyond the " Red Ore " lies the Miller pit, a very large and very interesting ore body, now practically worked out. The Miller is presumably the faulted extension of the Old Bed, which is dropped to the west, but it has in sections 7–10 a very peculiar double character. The separate parts of No. 7 coalesce in Nos. 8 and 9 and part again in No. 10, beyond which to the south the upper one, once the large one, fails entirely. We are confronted with some difficulties in following out the folds in whatever way we may try to explain them. We must consider the Miller as an expanded prolongation of Old Bed before folding; that is that the Miller was longer north and south, so as to allow for its extended pod in sections 13–18. Probably the under one of the two pods in No. 10 was connected with Old Bed and was doubled over on itself as shown in Nos. 7 and 8. It must either have been this or else the upper member is the prolongation and the bed was doubled under itself to account for Nos. 7 and 8; or else the Miller is a forking pod, from a central thickened portion in Nos. 8 and 9, where the two parts coalesce. Any of these three relations is possible, but if we favor folding we can not avoid giving great emphasis to the viscosity or doughlike consistency of the rocks at the time, since in no other way could they possibly have bulged and molded themselves into these forms. So pronounced is this character that one can not well help giving serious attention to possible convolutions in a molten but ropy mass. Under the latter assumption we need infer burial in the earth at a less depth in order to make the results possible.

The following analyses illustrate the composition of the ores from the " 21 " pit. No. 1 was a sample of 65 carloads and No. 2 of 35 carloads from the Port Henry Co.

	1	2
Iron	60.03	60.91
Silica	4.48	4.49
Phosphorus	1.635	1.548
Sulfur	.021	.027
Titanium	.12	.03
Copper	......	.007
Moisture	.28	.25

When the phosphorus is recast as chlorin apatite, it gives for No. 1, 9.14, and No. 2, 8.83. Calculating all the iron as magne-

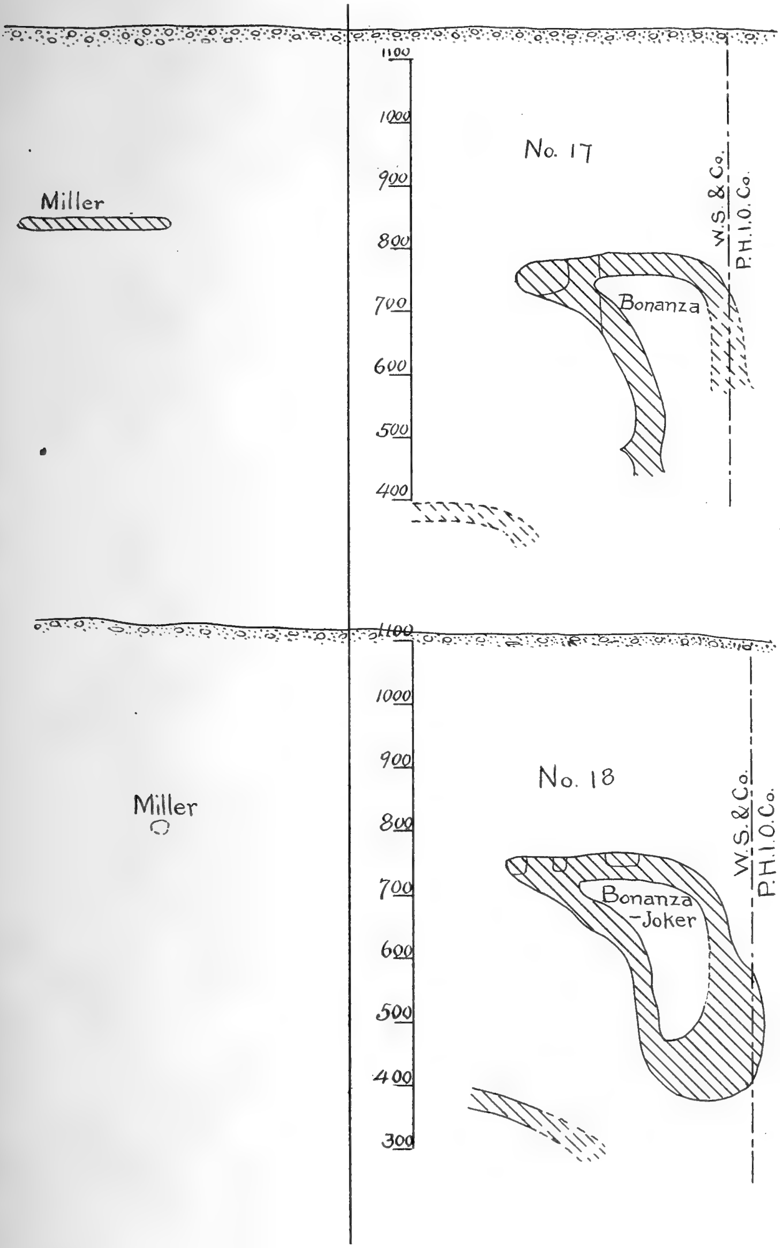


Fig. 24 Sections 17 and 18 of Old Bed ore bodies, Mineville. *See* figure 19

tite, this mineral then formed in No. 1, 83 per cent of the mass; in No. 2, 84 per cent. In the sample and undetermined there was more than five per cent of CaO, and probably a little Na_2O, attributable to the green pyroxene often observed in the ore.

The analyses below, taken from the *Iron Age* of December 17, 1903, show the composition of the crude Old Bed ore and the products made by its concentration at the milling plant of Witherbee, Sherman & Co. No. 1 represents the crude ore, No. 2 the magnetic concentrates, No. 3 the first grade apatite product made by retreatment of the tailings from the first concentration, and No. 4 the second grade apatite product.

	1	2	3	4
Iron	59.59	67.34	3.55	12.14
Phosphorus	1.74	.675	12.71	8.06
Bone phosphate	......	....	63.55	40.30

Harmony mines. The most recent developments at Mineville are the two Harmony shafts, A and B, which were sunk 5 or 6 years ago in order to tap a bed of ore revealed by the dipping needle and the drill to the south and somewhat to the west of the Joker workings, and at a much higher horizon. The Harmony bed strikes northwest and dips southwest at a rather flat angle. It is 10 to 20 feet thick and is cut by at least 3 narrow trap dikes with a strike a few degrees east of north and a vertical dip. They fork somewhat and are not absolutely continuous. The dikes occupy small faults of 10 to 50 feet displacement and strike in a direction to suggest that they are the same as the two in the Miller pit.

The relations of the Harmony ore to the Joker on the one side and the Barton Hill group on the other are interesting. Our last section of the Joker is 500 feet above Lake Champlain, while the outcrop under the drift of the Harmony bed, 400 or 500 feet away, is 450 feet higher. If the latter is the prolongation of the former there is a very great fault in the interval. On the other hand, if we attribute to the Barton Hill group a swerve to the eastward under the cap of drift, there is a very strong probability of connecting up with the Harmony bed. There is unexplored ground in between with evidence of some disturbance. The composition of the Harmony ore as regards phosphorus is intermediate between the Barton Hill and the Joker. It is higher than the former and lower than the latter. The percentage in iron is somewhat less than the Joker.

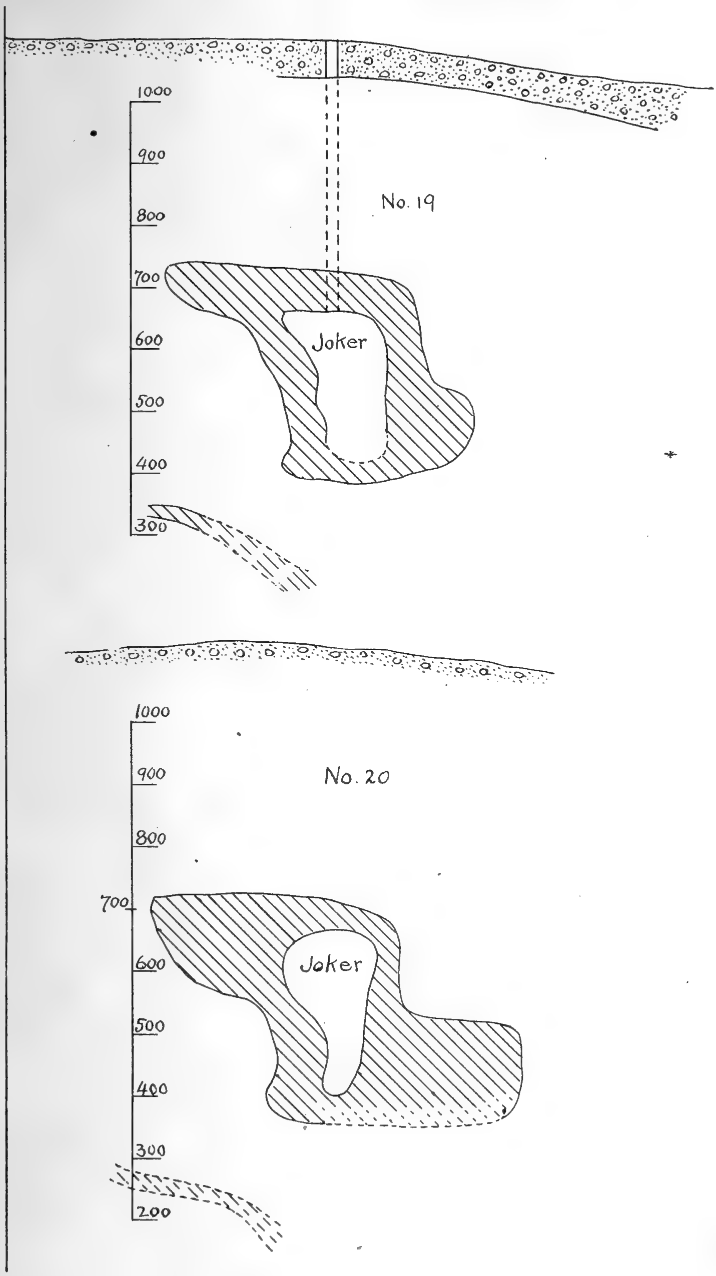


Fig. 25 Sections 19 and 20 of Old Bed ore bodies, Mineville. *See* figure 19

A third possibility must be considered, namely, that it is a totally distinct bed having no necessary connection with either of the older ones. While it is natural to seek to connect those already known, it must be admitted that the last view can not be entirely ruled out.

Barton Hill mines. These openings are distributed along a practically continuous bed whose outcrop is approximately 3500 feet long in a direction a little east of north. From the 1300 contour on the south, the outcrop rises to the 1750-foot contour on the north. From the southern end of the outcrop the underground workings follow an extended shoot of ore some 2000 feet farther on a flat dip to the southwest; and along its axis this particular branching pod must be fully half a mile long.

Taking the Barton Hill bed as a whole it is characterized by swells and pinches giving the enriched and thickened shoots which have been specially followed in the mines. Their axes and therefore the workings run northeast and southwest and are closely parallel with the Old Bed group, and with the Harmony beds. No doubt the relationship is due to the general system of folding which prevails in the gneissoid rocks and which has caused the rolls and attendant bulging. Upon the map of the Mineville area [fig. 19] the successive openings are given. They begin on the south with the New Bed, which is the deepest and most extensive. Then follow the North pit and the Arch pit, of moderate extent. From the Arch pit a tunnel is now being driven northwest on a slightly ascending grade so as to bring out by a gravity tram, the ore which may be tapped in the downward extension of the more northerly shoots. Already some gratifying discoveries have been made.

The next pit on the north is the Lovers Hole, the famous opening from which came the extremely rich ore and the remarkable crystals of magnetite, mined about 1887–88. A total of 40,000 tons from one chamber averaged 68.6 per cent and carload lots ran 72 per cent, being almost chemically pure magnetite.

Beyond the Lovers Hole is a stretch not much mined as yet, and then as the outcrop swerves with the contours to the northwest, there are three pits, the South, the North and the Orchard. The rock dumps are large at this end, indicating leaner ore. Beyond the Orchard pit, there is an interval with no mines, and mostly with concealed bed rock, for half a mile. Within this distance there is a drop of 150 feet in the altitude and then two groups of mines, now for some years unworked, are found. These are the

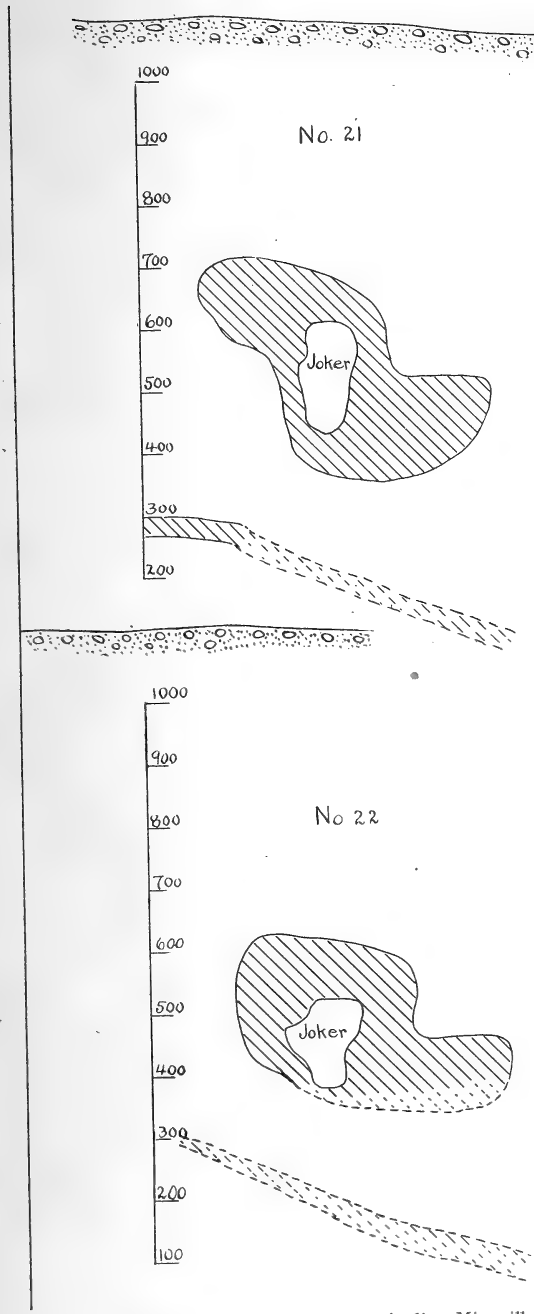


Fig 26 Sections 21 and 22 of Old Bed ore bodies, Mineville. *See figure 19*

Fisher hill mines belonging to the Port Henry Iron Ore Co., and the Burt lot, of Witherbee, Sherman & Co. The ores are rather lean but are of Bessemer grade.

The pits are distributed across a horizontal stretch of 100 feet at Fisher hill and 250 to 300 feet at the Burt lot. They dip about 25° westward, and are therefore something like 40 feet apart vertically at the former and 115 feet at the latter. There are no marked horizons of ore within these limits. At Fisher hill the workings are 600 or 700 feet down on the incline, and at the Burt lot, 300 or 400. The railroad has been dismantled for 10 years past and the mines have been allowed to fill with water.

It is quite possible that the Fisher hill and Burt lot ores are a reappearance of the Barton hill bed after a lean interval, and that they mark a northerly continuation of the latter. It is very natural to infer these belts and especially are we prone to do so in so far as the time-honored sedimentary conceptions of origin influence us. The northern pits are double to a degree not shown by the southern, and if we are influenced by the igneous views, we may not feel justified in inferring the identity without proof of the connection. The wall rocks are practically identical and the general dip and axial trend of the pods correspond.

To the east of Fisher hill and a half mile away upon the eastern slope of a different hill is another great lens or pod now known as the Smith mine, and actively worked by Witherbee, Sherman & Co., through the Cook shaft. This pod was discovered by the needle. It does not outcrop. It dips west and pitches south like the others and furnishes a non-Bessemer ore much like Old Bed, but lower in phosphorus. A vertical shaft taps the upper end of the pod and then from the foot the two skipways fork and proceed southwest, one going for about 1000 feet. The ore varies from 20 to 40 feet thick, and at the south drops over 600 feet below its high point on the north. At the southern end is the old O'Neill shaft, now used for pumping and in the fall of 1907 tapped by the northern workings.

Two hundred feet or so north of Cook shaft, is the Thompson, long abandoned, and beyond this an interval of some distance with no workings. Recently diamond drilling has, however, revealed ore, which may in time be worked. The hill then abruptly drops away to a small valley, on whose northern side are two old mines, the Hall and the Sherman, which were early discovered but which have long been idle. The property has passed to Witherbee, Sherman & Co., and has lately been drilled. Ore has been found

Plate 19

Fisher Hill mines when active in 1896

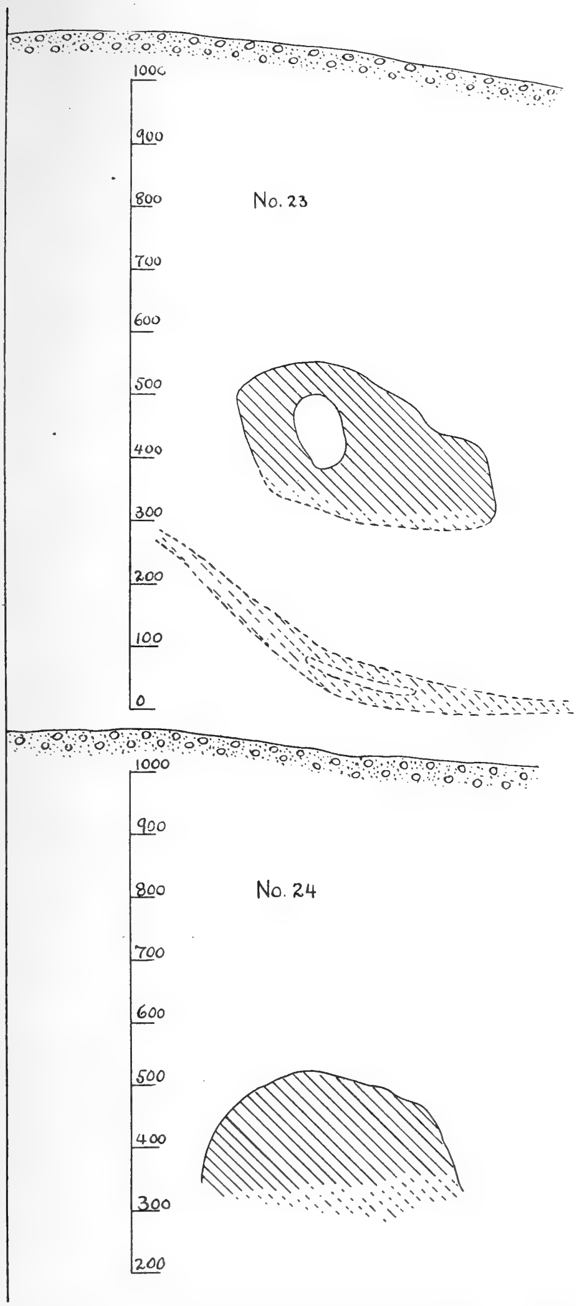


Fig. 27 Sections 23 and 24 of Old Bed ore bodies, Mineville. *See* figure 19

in rocks the same as at Mineville, and constitutes a reserve for the future.

It is natural to consider these last mentioned beds the northern extension of the Smith mine, and it as representing the Old Bed group, farther east and lower down than the Barton hill-Fisher hill-Burt lot series; but inasmuch as the O'Neill shaft is over a mile from the last exposure of the Old Bed series with almost no outcrops between, and in rocks that are practically massive, one may quite as well regard the northern ones as totally distinct ore bodies. Again one's train of thought is necessarily influenced by the sedimentary or igneous views of origin. The axial trend of the Smith mine is parallel to the same feature in all the others to the south, and therefore shows the same great structural character, presumably due to folding, whose compressive strain being at right angles to these axes, operated in a northwest, southeast direction.

Geological relations. Up to the time of the appearance of the writer's paper on "The Geology of the Magnetites near Port Henry, N. Y., and Especially those at Mineville," in the *Transactions of the American Institute of Mining Engineers,* 1898, volume 27, pages 146–204, the wall rocks of these great ore bodies had been generally described as "gneiss," and had been with entire justification regarded as the usual run of these ancient metamorphics which habitually contain the magnetites. By mapping of each outcrop and parallel observations underground and by microscopic determinations it was shown that there are several distinguishable types of gneiss present, and one intrusive gabbro. In the "Old Bed" group, of which the "21" mine is the chief, the hanging wall is a very light colored acidic variety which was called the "21 gneiss." It is a granitoid aggregate, consisting essentially of microperthite and quartz. With these and in subordinate amounts are plagioclase, magnetite, titanite and zircon. Of the last named magnetite is the chief, and often the scattered grains might easily give the observer the impression that they are some dark silicate. Still, were a stray crystal of the emerald-green pyroxene also to appear, it would not be surprising, although one is rare. An analysis of the rock is given on pp. 49 and 50 and a recasting for its mineralogy.

Additional study of many drill cores, and further observations in the mines have served to corroborate the above determination.

The great ore body lies beneath a cap of this very acidic rock. The "21 gneiss" appears at times at other horizons in the series but it is not always accompanied by ore. It is moreover very similar to the wall rocks at Hammondville, if not actually identical with them.

Beneath the ore appears a more basic variety, rich in hornblende, augite, and sometimes in biotite. Plagioclase is abundant and inasmuch as massive gabbro is seen beneath the Barton Hill ore, the basic gneiss was believed to be a metamorphosed representative of it and was called "gabbro-gneiss." Meantime, however, we have learned much regarding the syenitic series of the Adirondacks and have also obtained some thousands of feet of drill cores not previously seen. From the latter it is evident that representatives of the former are the chief members in the series. Many more slides of the supposed "gabbro-gneiss" serve to ally it with basic developments of the syenite series and it is much more defensible to consider the ores as lying between the two extremes, an acidic and a basic, of the great syenite series. In the basic we find so much microperthitic orthoclase that it is practically impossible to draw sharp lines of distinction among these varieties when starting from the normal syenitic type.

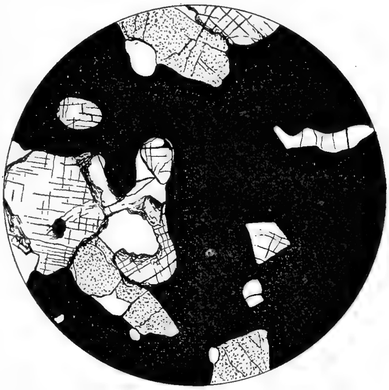


Fig. 28 Old Bed ore. The black is magnetite; the stippled mineral is apatite; the lined mineral is emerald-green pyroxene. Actual field 0.1 inch.

In the early paper a band of acidic gneiss was identified in the hanging wall of the Barton Hill group, and was called the "Orchard gneiss" after one of the pits. The rock was composed essentially of quartz and plagioclase with now and then a few magnetites and zircons. One related occurrence had microcline. This must be regarded as essentially a phase of the "21 gneiss," since in the one case the albite molecule crystallized as spindles in the orthoclase, yielding microperthite, while in the other it combined with a little of the anorthite molecule to yield oligoclase. The Orchard gneiss is soon succeeded, as one ascends Barton hill, by a darker variety containing microperthite as the most abundant mineral, with quartz, oligoclase and orthoclase as the other light colored components. The dark minerals are brown hornblende, emerald-green augite and rarely hypersthene. Apatite and magnetite are also

present. This was called the Barton gneiss. It is obviously the characteristic syenite of the Adirondack area as repeatedly described in later years by Cushing, Smyth and the writer. The additional study of the drill cores but serves to confirm its abundance in the series.

Lying below the Barton Hill ore body and between the Arch pit and the Lovers pit, is a goodly exposure of typical basic gabbro, so that there can be no doubt that this rock is represented in the hill in an important way. Exposures are fragmentary because of the ever present glacial drift, but the typical and unmistakable gabbro is succeeded as one follows along to the north, by a dark, basic and at times garnetiferous gneiss, which one might naturally and with great reason regard as a metamorphosed form of the gabbro itself. This was the view taken in 1898. Repeated and painstaking study of the exposures since then, and due consideration of the basic phases of the syenite series and of the character of the feldspars, which are largely orthoclase, have led to the conclusion that this basic gneiss belongs rather with the syenites than with the gabbros, and that the gabbro as seen is a separate intrusive mass. Yet it must be said that there are very puzzling things to be seen. Thus as one follows along the foot wall of the ore above the Lovers pit and toward the South pit, there are exposures of dark, gneissoid rock, apparently basic syenite, yet with many little garnets like the gabbro. Again beyond this point there is rock which is believed to be true gabbro as mapped in 1898. Yet as to the shape of the gabbro intrusive mass, no conclusion could be reached. It is involved in the basic gneiss, and so poorly exposed because of drift, that it is very easy to begin to speculate as to whether a mass of absorbed limestone might not locally change a syenitic magma into one gabbroic in character. Practically the same relations, equally puzzling in character, appear on the summit of the hill above the Smith mine, where garnetiferous basic (syenite) gneisses are again associated with gabbro in a very obscure manner.

In the close observation of this hillside below the Lovers pit, the writer also happened on what appeared to be a small dike, about 10 inches thick, striking with the schistosity of the basic syenitic gneiss, but cutting it on the dip. It is a quite acidic rock, and reveals in the slide, quartz and orthoclase as the most abundant minerals, less oligoclase, and a few shreds of dirty green hornblende, so molded around the other minerals as to suggest either crushing and dragging or secondary crystallization. There is a

little magnetite and a stray zircon or two. The rock is much more acidic than the walls within which it is found, but its mineralogical affinities with the acidic phases of the syenite are close.

It seems inconceivable that a little dike should occur alone, but no other eruptive masses have been detected with which to connect it.

Pegmatites. The ore bodies are occasionally cut by pegmatite dikes of a very coarse character and of interesting mineralogy. They are chiefly quartz and orthoclase, although oligoclase enters also into the aggregate. In the walls of Old Bed pegmatitic developments are characteristic of the edges and limits of the ore body and contain also coarse hornblende and large, coarse crystalline magnetite. They seem in some way to be associated with it in origin. In the "21" pit streaks of pegmatite run parallel with the general foliation and again give the impression of having been intimately involved with the ore at the time of formation. Allanite appears at times in these pegmatites and presumably from these or from others somewhere in this pit, Prof. James Hall obtained a superb crystal which was formerly in the collections at Yale University [Dana, E. S. On a Crystal of Allanite from Port Henry, N. Y., Am. Jour. Sci. June 1884. p. 479].

Ten years or more ago, in mining below the present floor of the "21" pit a large pegmatite vein or dike or mass was encountered, whose relations to the ore are not accurately known to the writer. Many tons of it were thrown on the dump and it was found to be rich in zircons, at times of rather large size and of great perfection. Much less frequent arsenopyrite also appeared and one specimen of a black coaly mineral, obviously one of those containing the rare earths, but not sharply determined. In this mass of pegmatite allanite strangely enough has not been detected. Magnetites of the familiar lamellar growth, with layers parallel with the octahedron faces, are abundant.

In the lower workings of the mines on Barton hill pegmatitic bodies of very interesting character have been encountered, some of which are now exposed in the new tunnel, which will further develop these lower lying ores. One mass of white fluorite with magnetite disseminated through it is cut by the tunnel and entirely forms one wall for a sufficient distance, to raise the question of its utilization. In other places in these workings white quartz and disseminated magnetite appear of obvious pegmatitic affinities. On the dumps of the North pit, scapolite enters into other pegmatitic lumps whose exact source in the old workings is

unknown. In a similar way large red garnets were at one time revealed in these same pits.

In the Smith mine, however, and from the Cook shaft which taps the northern end of this ore body, some of the most interesting pegmatite has been revealed. It consists of very coarse quartz and feldspar, with which allanite in irregular crystals up to the size of one's hand is richly disseminated. Rarely good terminations can be obtained, but the mineral is so brittle that it can not be freed from the matrix except by the exercise of great care [*see* Ries, H. Allanite Crystals from Mineville, Essex County, N. Y. N. Y. Acad. Sci. Trans. 1898. 16:327–29]. The dump is chiefly the product of early mining, although some pegmatite has come up in carloads of recently excavated waste rock.

These pegmatites and their associated minerals, some of them at least unusual in this abundance, are strongly suggestive of igneous phenomena and to the expiring stages of some intrusive mass they would naturally be referred. If, as seems most reasonable for Old Bed, "21" and Barton hill, we connect them with the ore, they must mark an attendant phase of its separation. Otherwise they must have come from some separate intrusive mass at a greater or less distance and one which it is not easy to identify. The basic gabbros would suggest themselves.

One can scarcely attribute the pegmatites to regional metamorphic processes.

Revision of local geology. The geologic map here given shows somewhat different relations in the Barton hill area in regard to the distribution of the gneisses and gabbro than were shown on the map published by the writer in 1898. It also introduces the syenite series as embracing the several gneisses called "21," "Orchard" and "Barton." The syenite series has been described on earlier pages, with analyses and calculations of mineralogy, which will serve to make the significance clear. As stated in the general discussion of the syenites, the ores are regarded as basic segregations in an eruptive mass of this character.

Origin of the ore. In all our work hitherto the gabbros have been believed to be the latest intrusive of the larger masses. That they penetrate the anorthosites as dikes is certainly true, because among others the great dike at Avalanche lake — at the source of the Hudson — shows these relations. As against the Grenville series they are also believed to be intrusive, although decisive contacts are not so clearly shown as with the anorthosites. But since the anorthosites are known to be later than the Grenville and older

than the other eruptives, there is no doubt that eruptives which cut the anorthosites are themselves later than the Grenville.

When we come to the relations of the gabbros to the syenite series, especially in the vicinity of Mineville, there is much obscurity. When field work was first done by the writer in this area, the syenites had not been recognized as such, and the rocks, which we now believe to be embraced under them, were called hornblende-gneiss or augite-gneiss. In these gneisses the gabbros when discovered were believed to represent intrusive masses whose boundaries, because of lack of exposures, could not be delimited or discovered. They were so involved with hornblendic gneisses that the latter were believed to have been derived from the gabbros. But as already outlined very careful revision of the exposures along Lake Champlain and on Barton hill, coupled with close microscopic study of the drill cores, has shown the following relationships. From the normal aggregate of feldspar and augite or hornblende, or, less often, hypersthene, the feldspar predominating, the syenites develop into basic bands in which the dark silicates are in excess. Yet there is no marked difference in kind of minerals, only a change in relative abundance. Garnets also appear, though not frequently, and the rock becomes indistinguishable to the eye from somewhat gneissoid derivatives of the gabbros. In the writer's former paper [1] gabbros were mapped on Barton hill near the Arch pit and again farther north near the Orchard pit. Between these exposures of undoubted and typical gabbro there is the stretch of dark basic rock, which we also associate with the syenites. Careful study has failed to show any recognizable contacts between the two, or more than a gradual transition. One can not say where the one ends and the other begins. Either the basic syenitic phases develop at times into gabbros, possibly by infusion of limestones from the Grenville or else the gabbros have been in some places metamorphosed to hornblendic rocks indistinguishable under ordinary examination from basic phases of the syenite.

In the belief that the basic gneisses beneath the ore represented the gabbro elsewhere seen in the foot wall in its massive form, the writer developed in the former paper the interpretation of the ore as a contact effect of the intrusive gabbro. In the present paper the immediate wall rocks of the ore bodies have been consistently described as members of the syenite series. With this change goes inevitably a modification of the earlier interpretation of origin.

[1] Am. Inst. Min. Eng. Trans. 1897. 27:146.

Rather than contact developments along an intrusive mass of gabbro, they have been spoken of as basic segregations in syenites. Both these interpretations are opposed to the still older belief that the ores are of sedimentary origin and the question may be perhaps stated with the arguments pro and con at this point. It is the more appropriate because among those actively engaged in mining and widely also among geologists having occasion to deal from time to time with other magnetite bodies in the Adirondacks, the rocks and associated ores are regarded as sedimentary in origin.[1] The writer while favoring the igneous conception disclaims any personal bias toward it, other than that it has seemed to be the simplest and least objectionable interpretation of rocks, confessedly puzzling.

The ores do certainly imitate to a marked degree the folds and similar structures of the stratified rocks, with perhaps this qualification that the folds are of an extreme type, being overturned, stretched and doubled up together in a very violent way. If sedimentary they must have been folded under such extreme pressure that the rocks flowed after the manner of viscous materials. In no other way could the Tefft shaft ore body have been pinched away from the main mass of the "21" pit. These folds are undoubtedly not essentially different from others well recognized in regions of metamorphosed, sedimentary rocks. The cross sections of the Alps for instance show many cases of the same sort.

On the other hand if one imagines a molten magma, differentiated into layers of contrasted composition, layers which range from acidic extremes to basic, then squeezed into folds either while yet viscous or after consolidation, the result would be the same. That this differentiation takes place in magmas is one of the growing convictions of students of eruptive rocks. It is certainly well enough established to justify giving it serious consideration. It may perhaps not unjustly prevent us from taking the sedimentary nature of the rocks as positively established because of the folded structure.

Another feature which has been esteemed proof of the sedimentary origin is the persistence and faithfulness of the ores in stratigraphic position. In the case of the Barton Hill group, they certainly do extend as much as a mile on the strike and are persistent for this distance. If we unwrap the Old Bed group from its folds and reconnect the faulted blocks they will extend,

[1] See for example W. L. Cumings, "On Sedimentary Magnetites." Engineering and Mining Journal. July 7, 1906. p. 25.

in one dimension at least over half a mile. This is certainly on the face of it suggestive of sedimentary stratification, but in fairness we might say that it could also be derived from a persistent, differentiated layer in an igneous magma. It is of itself scarcely conclusive on either side.

Another feature is the podlike distribution of the ore, affording its swells and pinches, and its tendency to a shinglelike distribution of the larger ore bodies. This structure is most pronounced in the Barton Hill group and is less evident in the Old Bed series which, as thus far developed, are more like one enormous folded pod. As long ago as 1881, the relationships of ore and lighter minerals in the tailings of mills, which were engaged in concentrating iron ores by wet processes, impressed H. S. Munroe[1] as imitating the lenticular shape very clearly and the same relationship has been noted by others since. The concentrated black or magnetite sands, which we not infrequently observe on beaches and along rivers draining areas of magnetite-bearing rocks, are likewise suggestive. They have given much support to the sedimentary view, and it is not so clear that heavy layers of eruptive origin would assume these forms, unless compressed strongly while still viscous. It must be admitted that while not perhaps conclusive, yet the lenticular shape does accord best with sedimentary deposition.

Another consideration, which must be emphasized in the interpretation of the rocks, concerns their mineralogy and their parallelism with other known cases. There is no doubt that the most abundant rock in the cores has exactly the mineralogy and the texture of the syenites as elsewhere identified. H. P. Cushing has shown these syenites to be beyond question intrusive in their nature. They contain fragments of the Grenville series, undoubtedly caught up in a molten mass. They present irruptive contacts with the anorthosites, penetrating the latter in dikes and tongues. Their mineralogy is essentially that of the eruptive rocks, the augite and hypersthene especially being foreign to the metamorphosed sediments. While the ores are often intimately associated, especially with the very acidic phase, described above, and while both these varieties differ from the normal syenite, yet they are so involved with it, that it is quite impossible to believe that they are sedimentary and the syenite eruptive. They all hang together in one essential whole or entity and it is almost impossible to regard one

[1] School of Mines Quarterly. 1881. 3:43.

as different in origin from the other. The syenite has practically convinced the writer that being igneous itself, it carries inevitably into the same great group of rocks all the associated rocks, whether they consist of acidic, or basic silicates or even of ore itself. Hence this consideration is esteemed of greater weight than the coincidence of the pod or lenselike shape with undoubted sedimentary structure, and, in the interpretation of the nature of the ore bodies, the preference is given to igneous processes.

If we grant for the moment that the ores are of igneous origin and endeavor to understand the possible causes which have led them as well as the more basic and the more acidic phases of the syenitic rocks to form, we find ourselves confronted by great obscurity. It is believed by many that some sort of segregative process leads to this separation, just as pots of nickle-copper matte rearrange their composition in a fairly constant way in the few moments of cooling; or as pigs of base bullion, homogeneous when molten, are diverse when chilled. Some kind of physical-chemical force must assert itself and produce the variation. In connection with igneous iron ores, whose common mineral magnetite and its associated apatite are the first components of a fused magma to crystallize, many have thought that these two, being heavier than the magma, have settled out by gravity and have become concentrated as soon as developed. Subsequent flowage might then drag them out into bands, and rearrange their position with regard to relative depth. It is interesting to note the occurrence of the ores immediately beneath very silicious layers at Mineville, but the silicious or "21" gneiss as it now stands does not represent sufficient normal syenite to have yielded the vast quantity of magnetite now found in the ore. The separation must have taken place elsewhere. In a viscous flowage, it is conceivable that the bulging folds might have been yielded under pressure, and some of the difficulties afforded by such extreme local folding of sedimentary rocks may be avoided.

In June 1909 in the *American Journal of Science,* page 421, F. E. Wright and E. S. Larsen published a very interesting and significant paper entitled "Quartz as a Geologic Thermometer." The point of importance is this. When silica crystallizes above 800° C. tridymite is the form assumed, but when it crystallizes below 800° C. quartz is the result. Furthermore when quartz develops between 575° C. and 800° C. it assumes one division of the hexagonal system (apparently the trapezohedral-hemihedral); while the quartz which forms below 575° C. falls in another divi-

sion (the trapezohedral-tetartohedral). As a result of these differences, certain contrasts of physical and optical properties arise which cast light upon the temperature at which any individual quartz has crystallized. Experimental tests have shown that the quartz of veins and pegmatites is prevailingly of the variety below 575° C., while the quartz of granite and related igneous rocks belongs in the variety above this critical temperature. The two may be distinguished by certain optical properties and by etching.

As a test of the nature of the rocks associated with the magnetites, the writer asked Dr F. E. Wright to make some trials of their quartzes. With great kindness Dr Wright consented to do so and obtained the following results in the laboratory of the Carnegie Institution in Washington.

Specimen 196A came from diamond drill hole 196 in the Lower Bonanza mine and was a piece of core from a point a foot or two below the ore. A dark hornblende or pyroxenic variety lies immediately beneath the ore, but within a foot or two the dark silicates decrease giving the more feldspathic and quartzose specimen which was tested. Five plates were cut of which three had the characters of the quartz below 575° C. and two those of the variety above this temperature. Dr Wright inferred that the quartz on the whole rather favored the low temperature variety formed near the critical point 575° C.

Specimen 196C came from the same drill core about 72 feet below the ore. The rock was considered a typical case of the syenite. Seven plates were cut, of which five favored the high temperature variety, and two the lower form. The conclusion reached was that these quartzites probably formed not far from the critical temperature of 575° C.

Specimen 140IV was taken from the core of hole 140, located west of the Harmony A mine. The hole cut a thin bed of magnetite. Ten plates were cut of which five were characteristic of high temperature quartz and five of low. Probably, as in the other cases, the temperature of formation was not far from 575° C.

Seven plates were prepared of the lean quartzose ore from the Nichols Pond mines described below. The tests indicated that this quartz had never reached 575° C.

These lines of evidence are not so decisive as was hoped but at all events they indicate that the rocks have passed through quite exalted temperatures. If not positively those of igneous fusion they are none the less so high as to preclude the mere burial and metamorphism of sediments. Thus if we allow a normal increase

of temperature of 1° C. for each 100 feet of descent, we call for 11 miles of depth to reach 575° C. This is beyond the belief of a conservative mind and forces us to the assumption of some localized source of heat, i. e. intrusive rocks. We may think of the ore as being more or less akin to pegmatites in its formation, and of the walls as perhaps being formed somehow under the influence of mineralizers so as to require less exalted temperature of crystallization than normal eruptives, but igneous phenomena and influences in some form we can not reasonably escape.

Unsatisfactory as the available suggestions of origin may appear, it should always be realized that we are dealing with very obscure and difficult questions at best, and with rocks of great age and of complicated history. To whatever portion of the world we turn for the results of similar studies, we find geologists involved in the same difficulties. The best that one can do is to present a candid statement of the case leaving for the future such further light as the general advance of the science may afford.

Nichols Pond magnetite. From 3 to 3½ miles north of the Fisher hill and Hall mines, there was formerly active a small enterprise based upon an exposure of magnetite on Campbell mountain

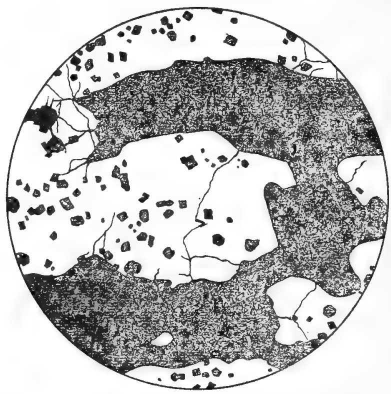


Fig. 29 Lean magnetite, Nichols Pond pit. The white is quartz; the black magnetite. The aggregate resembles a quartz vein with magnetite. Actual field $\frac{1}{10}$ of an inch.

a mile west of Nichols pond. The principal open cut is practically on the summit of the mountain so that from it one looks away to the north across the valley of the Black river. According to J. C. Smock [N. Y. State Mus. Bul. 7, 1889, p. 36] operations were begun in 1845 and continued to 1850. The openings are on lots 166 and 168 of the Iron Ore tract. Either at this time or later a concentrating mill was erected upon the shores of Nichols pond

and a tramway was built across its northern end which passed eastward descending some 700 feet in about a mile and a half to the first highway in Westport.

The deposit is lean and lies between acidic and basic gneisses very like the Mineville succession, if not identical with it. So far as one could judge, subject to local attraction, the strike was n. 35° w. true, and the dip 60° west. The section of the large and more northerly pit is as follows:

1 Hanging wall, typical, green massive syenite.
2 Lean mixture of magnetite and quartz, 12–15 feet thick. This is illustrated in figure 29 drawn from the microscopic slide. This association is unusual, and has not been elsewhere seen.
3 Still leaner mixture of the same general character, 20 feet.
4 Compact, feldspathic rock, 15 feet.
5 Lean mixture of magnetite and quartz, extending under cover.

The open cut was 75 to 100 feet long, 50 feet across, and had a wall about 25 feet high at the back. To the south, on the old road to Nichols pond, is another pit 15 x 15 feet. Hornblendic gneisses, presumably syenitic are shown in the foot wall, but the hanging was concealed.

Professor Smock states that the ore was reported lean and titaniferous, but the association with quartz would make the last statement unlikely. Professor Smock did not visit the mine. The leanness and remoteness are sufficient explanations for the cessation of operations.

Gates and Noble mines. Along the easterly front of the ridge which lies between Lincoln pond and New Russia there are several abandoned pits which were formerly operated to supply the forge at New Russia. Professor Smock in Bulletin 7, page 34, places the Gates mine on lot No. 138 of the Iron Ore tract. No work has been done since 1882. Professor Smock states, "The ore has been opened a length of about 20 rods, and in one shaft to a depth of about 140 feet, and has been found to range from 2 to 16 feet in width. The strike is north-northeast and the dip of the ore bed 60° westerly. The ore is fine crystalline and averages about 50 per cent of metallic iron. Northwest of the above described opening, and in the lower ground the Vulcan Iron Company of Boston, opened a vein of ore, which was 12–20 feet wide. The ore was remarkably fine grained. The greatest depth reached was 70 feet. The ore from these mines was used mostly

in the forge at New Russia. About 10,000 tons were obtained from the Gates mine. No work has been done in there since 1882."

The mine was also visited by B. T. Putnam as agent for the Tenth Census in 1880. His record on page 118, volume 15 of the Tenth Census Reports, is also of interest, the more because the observations of those who saw the now abandoned pits in operation, are better than anything attainable today when they are filled with water.

The *Gates* or *Putnam* mine is situated in Elizabethtown township, northwest of Lincoln pond and about 1 mile southeast of the village of New Russia. It is on Gate's farm, but the mine itself has recently been bought by Herbert A. Putnam, and is worked by him for the supply of his forge at New Russia. The existence of a vein of ore here has long been known, and about 12 years ago the Bay State Iron Company opened a mine some 50 rods north of the present workings. Their pit is reported to be between 200 and 300 feet deep (measured on the dip). It is now full of water. Work on the Putnam mine was begun in January 1880. In May 1881, the pit was about 100 feet deep, measured on the foot wall, which dips 57° to the west, and at the bottom 60 feet long. The ore varies in thickness from 18 inches along the sides of the pit to 4 feet in the middle. It will average, perhaps 30 inches. The direction of the outcrop is a few degrees west of north.

A part of the ore is coarsely granular and contains granules of apatite. Before it is used in the forge it is concentrated in the usual manner. Sample no. 1197 represents the ore as it comes from the mine, and sample no. 1198 the separated ore. The samples contained

	No. 1197	No. 1198
Metallic iron	43.21	64.14
Phosphorus	0.456	0.136
Titanic acid	Present	Present
Phosphorus in 100 parts iron	1.055	0.212

It takes about 2 tons of "primative" ore to make 1 ton of separated ore.

The Gates mine was also visited at different times both by the writer and by D. H. Newland when assisting in the field. An open cut about 20 feet wide and dipping 55° southwest was observed. The hanging wall is a dark hornblendic or pyroxenic gneiss, and the foot wall a light colored granitic rock. Very much the same contrasts are thus shown as at Mineville. To the west of this and the Nigger Hill pit much gabbro appears in a series of small hillocks.

Nigger Hill mine. To the south or southwest of the Gates pit is another opening locally called the Nigger Hill, but also described

by J. C. Smock as the Noble mine. Professor Smock records the following in New York State Museum Bulletin 7, page 34, 1889.

Noble mine, Nigger hill, Elizabethtown, Essex co. Another mine of the Champlain Iron Company on lot No. 136 of the North Riverhead tract. The ore has been opened for 150 feet, on a side hill, on the outcrop. The vein is 11 feet wide. The ore bed was first discovered in 1825. No mining has been done in 15 years.

Mr Newland also visited the pit pointed out as the Nigger Hill mine, but whether it is the same one as described above may be uncertain. He observed a pit 60 feet long by 30 to 40 feet wide, opened by stripping off some 6 feet and less of gneiss in order to expose a very flat bed of ore beneath it. The overlying gneiss was a basic hornblendic variety, apparently a member of the syenite series, but the underlying was not recorded. This very flat position of the ore is unusual since the dips of the gneisses are as a rule steeper. It probably chanced to be left by the general erosion at the crest of an anticline or in the trough of a flat syncline. B. T. Putnam did not visit the mine for the Tenth Census, so that no analyses have been recorded.

From some stray notes of Professor Smock there may be other small openings in this hill, but if so, we have not seen them.

Small pits near New Russia. The sudden fall of the Boquet river at New Russia affords a water power which occasioned the erection and operation of a forge during the period of the bloomaries. Ore was naturally sought in the neighborhood and at other points than the Gates and Nigger Hill pits. A series of small beds was discovered along the west side of the valley and small excavations were made at three or four points. To these the writer was guided by Mr Frank Morehouse of New Russia. The most southerly one is the Pitkin bed which was in the foot of the hills just west of the highway about ½ mile south of New Russia. A small pit had been sunk on a thin bed of ore.

Next north is the Castaline a short distance up the valley of Roaring brook and on the south side. Speaking of this and others near, Professor Smock in Bulletin 7, page 34, states, "West of the Boquet river in this town magnetic iron ore in workable extent has been discovered on what is known as the Castaline place, north of New Russia and in the Wakefield, Post and Ross veins. . . Since the stopping of the forges these mines have lain idle. The Castaline is one of the oldest openings in the country. Watson, in his history of Essex county, says that ore was taken out of it about 1800 and used in forges."

Some small pits were located by the writer after search in the woods, but they had long been abandoned and from them few details could be gathered. The rock in the vicinity was a basic, hornblendic variety and was considered a derivative of the gabbros, raising the question of titanium, but no analyses have been made.

The Ross ore bed is in the easterly foot of Oak hill about a mile north of New Russia. There is a lower opening and an upper, perhaps 300 feet vertically higher up. The lower opening, believed to be the Ross bed, exhibits streaks of magnetite in well foliated hornblendic gneiss, while a hundred yards east and 75 feet below, appears acidic gneiss, so that the familiar Mineville section is again shown.

The upper opening is in gneissoid gabbro with massive gabbro near. It is a lean ore 4–5 feet thick striking northwest and dipping at a flat angle to the west. An analysis of a sample by W. F. Hillebrand gave the following [U. S. Geol. Sur. 19th An. Rep't 1899, 3:408]:

TiO_2	5.21
FeO	22.81
Fe_2O_3	30.34
SiO_2	21.42
Al_2O_3	7.03
Cr_2O_3	none
CaO	3.59
MgO	6.92
K_2O	0.41
Na_2O	0.53
H_2O	0.95
P_2O_5	0.14
S	0.04
Cl	0.42
CO_2	trace
C	trace
Mn	trace
Total	99.81
Fe	38.98

This ore is not very high in titanium but it really belongs in the group of the titaniferous magnetites which will be taken up separately. It is curiously high in chlorin, leading one to suspect the presence of scapolite, since the apatite is obviously too small to care for it.

Steele ore bed. Aside from the titaniferous magnetites this is the one remaining occurrence met within the area. It is situated

about a mile southeast of Elizabethtown village and is exceptional in having a thin bed of limestone of the Grenville for its hanging wall. The pit was filled with water so that the lower edge of the ore was not seen. The exposed face was cut by a small fault which is illustrated in figure 30. The ore is a granular magnetite,

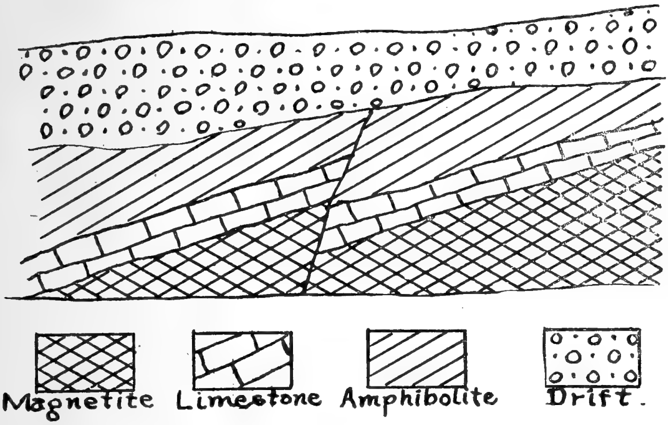


Fig. 30 Cross section of the Steele ore body near Elizabethtown.

and has an apparent strike northeast with a dip west. In only one other instance has ore in or next limestone been noted in the eastern Adirondacks and that is the Weston bed, near Keene Center. Limestones are not far, however, from both the Cheever and the Pilfershire beds, in each case in the hanging.

b The titaniferous magnetites

The interesting mineral deposits of this character are more numerous in the Elizabethtown and Port Henry quadrangles than elsewhere in the Adirondack region, but they are individually not as large nor as rich in iron as are those near Lake Sanford, at the headwaters of the Hudson and in the Santanoni quadrangle. The geological associations are also different. The Lake Sanford bodies are in the anorthosites, whereas, the ones here specially treated are in the basic gabbros. So far as our detailed explorations have gone, the basic gabbros seem to reach their greatest development in the area covered by the two quadrangles here described and extending a short distance north and south. Throughout their many exposures the titaniferous magnetites occur rather frequently and while at present not possessing commercial values as sources of iron, they are of much scientific interest.

The basic gabbros in this section favor the borders or general

contact belts between the anorthosites and the other rocks to the eastward. They form irregular masses of a square mile or less in area, and have revealed few details which would enable the observer to describe them as laccoliths or intruded sheets, or stocks. They certainly do appear in dikes, and the larger masses display characteristic irruptive contacts with the older rocks.

The bodies of magnetite or of intermingled magnetite and ilmenite are merely phases of the gabbro, exceptionally enriched with the iron-bearing minerals. There is no sharp demarcation between so called ore and rock. All the rock has some ilmenite-magnetite. All the ore[1] contains some of the common minerals of the rock, viz: olivine, pyroxene, and garnet, but the feldspar tends to fail. We are compelled therefore to regard the ore bodies simply as basic phases of the gabbro, exceptionally enriched with one of its normal minerals. Details of these relationships will be brought out under descriptions of the individual ore bodies, of which some 10 or more have been discovered. In earlier years much attention was directed to them and in at least four instances they have been opened on a scale which has left pits and tunnels of no small size. In one instance, the Split Rock mine, a magnetic mill was built in the hope of reducing the titanium.

The several deposits will be taken up from north to south so as to begin with the best known and most developed case.

Split Rock mine. From Westport to the northeast the shores of Lake Champlain are formed by a rugged ridge, known as Split Rock mountain, from the rocky islet which is, as it were, split off from its extreme point just beyond the limits of our map. Toward Lake Champlain it is precipitous and rough, forming a general fault scarp with many picturesque reentrant bays where cross faults intersect the master one. The summit of the ridge is very irregular but the northwestern slope is more gentle. On the precipitous eastern front and some 5 miles from Westport a mass of titaniferous ore is exposed at a point about 100 feet above the water. It attracted attention about 40 years ago, and as it stood in a position very convenient for mining and shipping it was opened up on a fairly large scale. Boarding houses were built in a notch in the ridge just above and in the end a mill was erected at the shore of the lake. A road leads out to the westward to the highway as shown on the map.

[1] The word ore is here employed in its purely scientific meaning as implying the richly metalliferous minerals; not in its technical sense as capable of being produced at a profit.

The ore occurs in a moderately large mass of gabbro which can be traced in the vicinity. It is a dark green or black rock, consisting of augite, hypersthene, brown hornblende, garnet, original basic plagioclase, charged with pyroxenic dust and minute spinels, secondary plagioclase in clear rims around the last named, and of the magnetite-ilmenite mixture. The ore is 10 feet or more thick, and forms a flattened body, which strikes into the hill n. 70°-80° e. and dips 50° south. An open cut has been excavated 30–40 feet deep and 25 feet high. From its mouth the old dump of broken ore streams like a talus down to the lake shore. To the south another small opening is reported but this has not been visited by the writer.

While the rock mass is faintly foliated from dynamic effects, there is no sharp transition from ore to rock. The former is simply a basic phase of the latter and the exposures are so good that this locality is a specially favorable one for the study of the relations.

In cracks through the ore a curious isotropic green substance is somewhat rarely found which contains some dusty magnetite and the decomposed remains of feldspar crystals. It has been previously described by the writer as a glass, but its identity can not be sharply determined without a quantitative chemical analysis. Its specific gravity is 2.822 which is higher than the common isotropic minerals which might occur in these relations.

An analysis of the wall rock has been made by W. F. Hillebrand and also one of the ore, nos. 1 and 2 below. No. 3 is an analysis by George W. Maynard, made in the early seventies. Nos. 1 and 2 are from the 19th Annual Report of the United States Geological Survey, volume 3, page 402; no. 3, Journal of the British Iron and Steel Institute, volume 1, 1874.

	1	2	3
SiO_2	47.88	17.90	16.46
TiO_2	1.20	15.66	14.70
Cr_2O_3	tr. ?	.51	....
Al_2O_3	18.90	10.23	.34
Fe_2O_3	1.39	15.85	38.43
FeO	10.45	27.94	23.40
NiO.CoO	.02	not det.	not det.
MnO	.16	tr.	.23
MgO	7.10	6.04	2.13
CaO	8.36	2.86	3.54
SrO	tr.	....	....
BaO	tr.	....	....

K_2O	.81	not det.	....
Na_2O	2.75	not det.	....
Li_2O	tr.	....	....
H_2O-	.18	....	....
H_2O+	.43	1.33	....
P_2O_5	.20	.04	....
V_2O_5	tr.	.55	....
CO_2	.12	.10	....
S	.07	.14	....
Total	100.02	99.15	99.23
Fe	......	32.82	32.59
Sp. Gr.	3.090	4.138	....

When recast the above analyses yield the following percentages which are approximate but unquestionably near the truth. No. 3, however, can not be recast with so great an excess of Fe_2O_3 over FeO.

	1	2
Ilmenite	2.13	29.42
Magnetite	2.09	22.97
Pyrrhotite	.18	.35
Olivine	16.93	....
Pyroxene	13.41	22.91
Plagioclase	56.70	13.62
Orthoclase	4.45	....
Apatite	.34	....
Calcite	.20	.20
Kaolin	3.10	....
Water	.18	1.33
NiO.CoO	.02	....
Spinel	....	5.97
Corundum	....	.92
V_2O_5	....	.55
P_2O_5	....	.04

In the quantitative system, no. 1 comes under class II Dosalane, order 5, Germanare, rang 4, Docalcic, Hessase, subrang 3, Persodic, Hessose; no. 2 falls in class IV Dofemane, order 4, Domitic, Adirondackare, suborder 3, Tilhemic, Champlainiore, rang 1, Permirlic Champlainiase, section 1, Permiric Champlainiose. These last names will suggest the large part that the Adirondack titaniferous magnetites play in the nomenclature of the system.

Ledge Hill mines. About 2 miles a little south of west from the village of Westport an abrupt hill rises to a hight of 1140 feet. On the northeastern side and a short distance below the summit two pits have been opened upon masses of ore in the gabbro. The ore

in one pit has a long dimension in a northeasterly direction and has been exposed in a cut 75–100 feet long and 30–40 feet deep. The second mass has a pit about 25 by 8 feet which is entered by a cut at right angles to its long dimension, and 15 by 15 feet in size. The pits can not be far from the 900 or 1000 foot contour. The wall rock is typical gabbro and while no analyses have been made of the ore, it has all the associations of the titaniferous varieties, is dense and characteristic in the specimens and is believed without doubt to belong to this variety. The name "Ledge hill" may not be the best one but it was given the writer in early work in the region. The locality is in lot 163 of the Iron Ore tract. The notes upon the pits were first published in Bulletin 14 of the New York State Museum, page 350, but the openings were again visited in 1907.

In the southeastern foot of this same hill, approximately on the 700 foot contour, and a short distance from the highway, there is another small pit in a very basic, hornblendic gneiss. Lean, dense magnetite is exposed which is apparently titaniferous. It is a small pit and no analyses have been made.

The remaining occurrences of the titaniferous ores are in Elizabethtown and Moriah.

Tunnel Mountain mines. The Black river heads in Lincoln pond in the southeastern portion of Elizabethtown and thence flows east of north through a wild and narrow pass in which was formerly located the old forge and little village of Kingdom. The relations both of the pond and the river are now somewhat changed from those depicted on the map, because of the damming of the river a few years ago and the erection of an electric power plant for the mines at Mineville. The pond is much expanded and the roads have been somewhat changed. At the point where the river begins to form the boundary between Elizabethtown and Westport, it rounds the foot of an eminence on the northwest, which is called Tunnel mountain, from an adit which was run many years ago near the summit. It was intended that the adit should tap a large body of ore which outcrops higher up.

At the eastern foot of Tunnel mountain, two small pits have been opened which at the time they were visited were on land belonging to John Tryan. The first was 15 feet square by 10 feet deep, and in lean ore which gradually shades into wall rock. It contained much biotite. A thin section revealed titaniferous magnetite, olivine, brown hornblende, deep brown biotite, garnet and clear,

unclouded plagioclase. The biotite is closely involved with the particles of ore. A partial analysis of the so called "ore" by W. F. Hillebrand gave the following:

FeO	21.34	TiO_2	10.55	V_2O_5	.34	S	.10
Fe_2O_3	11.52	Cr_2O_3	.25	P_2O_5	.46	Fe	24.65

The specific gravity was 3.199. The above percentages correspond to

Ilmenite	25.344
Magnetite	16.704
Remaining FeO	6.912

The association with biotite is unusual for the Adirondacks but has been noted in Brazil by O. A. Derby [Am. Jour. Sci. Apr. 1891, p. 311].

Two hundred yards northwest is another pit 15 by 30 feet and 10 feet deep. The walls are gneissoid gabbro and the ore resembles the usual run of the gabbro ores. No analysis has been made, but the specific gravity of 3.964 indicates more iron than the sample from the first pit.

At the extreme summit of the mountain which stands at 1640 feet a mass of ore outcrops, larger than the bodies at the foot, and indicating from its position a character of exceptional resistance to erosion and weathering. An open cut has been excavated 40 feet long, 10 feet wide, and apparently 40 or 50 feet deep. It is now filled with water and its depth is estimated by the size of the neighboring dump. The cut runs north and south and is parallel with the vertical foliation of the walls. Lean ore and gabbro (or strictly speaking norite) outcrop 10 or 15 yards to the west across the strike and gradually pass into the usual massive rock. Some 200 feet vertically below the summit and south of it, in the side of one of the characteristic cross gulches of the mountains an adit has been run with the intention of striking the ore in depth. It must be 100 to 150 feet long, and while it seems not to have cut the ore, it has yielded beautifully fresh samples of the country rock, besides giving the name to the mountain. When examined in thin section, the rock proves to be a true, gneissoid norite, hypersthene being the most prominent bisilicate present.

It is thus analogous to the basic rocks of Norway which contain titaniferous magnetite in that country. Green augite, brown hornblende, plagioclase and garnet are the other components. In the ore, the microscope reveals besides the iron minerals, brown hornblende, serpentinized olivine, garnet and colorless transparent labra-

dorite. An analysis of the ore by W. F. Hillebrand gave the following results:

SiO_2	13.35	P_2O_5	.02
TiO_2	16.45	S	.09
Al_2O_3	8.75	Cl	present
Cr_2O_3	.55	C	tr.
Fe_2O_3	20.35	H_2O	1.68
FeO	28.82	CO_2	.17
MgO	6.63		
CaO	2.15	Total	99.62
V_2O_5	.61	Fe	35.99

When recast this analysis may be split up into the following components which are undoubtedly very near the true proportions:

Ilmenite	30.80	Calcite	.40
Magnetite	29.80	Water	1.68
Chromite	.64	Vanadic oxid	.61
Anorthite	9.45	Sulfur	.09
Spinel	7.38	Phosphorus	.02
Olivine	6.94	Residue, SiO_2	.36
Enstatite	11.40		
		Total	99.57

In the quantitative system this has the same name as the one last recast.

It is probable that from the Tunnel mountain pit came the sample analyzed by Prof. George W. Maynard [British Iron and Steel Inst. Jour. 1874] under the name of the Kingdom Works. He gives

TiO_2	13.15	SiO_2	21.64
FeO	21.24	Al_2O_3	11.86
Fe_2O_3	23.77	CaO	3.54
MnO	.87		
		Total	96.07
		Fe	32.59

Professor Maynard also gives another under the name Iron mountain, Elizabethtown, but the exact locality is not known to the writer.

TiO_2	16.37	Al_2O_3	9.35
FeO	25.44	CaO	7.75
Fe_2O_3	30.36	MgO	.13
MnO	.47		
SiO_2	10.26	Total	100.13
		Fe	40.42

Pits near Little pond. Some 2½ miles south and a little east from Elizabethtown and back from the present highway is a small

lake, known as Little pond. An old road passes it and out through the valley of Kerner brook and is reputed to be the one made by the first settlers in entering what is now Pleasant valley. A little to the northeast of the pond and in two hillocks of gabbro, openings have been made upon bodies of titaniferous ore of considerable size. A great area of dark basic gabbro is present in these hills, and the openings have been excavated in masses of ore occurring in it. The north pit is 20 by 20 feet and 15 feet deep. The south pit, 200–300 yards southeast, is run in a hillside and is 30 by 30 feet. The working face is 25 feet high. The ore contains the same green isotropic substance described from Split Rock. Great expectations were raised by these ore bodies when first discovered; thus W. C. Watson in his History of Essex County, states that the ore forms an entire hill and is inexhaustible in amount.[1]

The wall rock of the pits is the usual green gabbro of this region. The ore is found on microscopic examination to contain, besides the ilmenite and magnetite, brown hornblende, olivine, garnet, and plagioclase. The following partial analyses by W. F. Hildebrand indicate the composition. When recast we obtain the third and fourth columns.

	North pit	South pit
TiO_2	18.82	13.07
FeO	29.78	28.35
Fe_2O_3	26.30	11.16
Cr_2O_3	.75	.37
V_2O_5	.62	.50
P_2O_5	tr.	.32
S.	.06	.10
Total	76.33	53.87
Fe	41.57	29.87
Sp. Gr.	4.41	3.83

	North pit	South pit
Ilmenite	35.27	24.49
Magnetite	38.05	16.24
Chromite	.64	.45
Pyrrhotite	.18	.26

Pit near Lincoln pond. Lincoln pond is the source of the Black river, and was earlier referred to, in speaking of the Tunnel mountain pits. A quarter of a mile west of it in a steep cliff of gabbro, an open cut has been run in on a mass of ore. The opening is locally known as the Kent mine, and it is the largest of all the openings in Elizabethtown. It is 15 feet wide by 75 to 100 feet long, and is continued by a shaft to an unknown depth, as it was full of water when visited. The wall rock is quite massive, and varies in composition from a true norite to a gabbro. Green augite,

[1] N. Y. State Agric. Soc. Trans. 1852. 12:649.

hypersthene, brown hornblende, plagioclase and ilmenite-magnetite are the chief minerals present, while microperthitic orthoclase does not fail. The close relations of the gabbros with the syenites are thus indicated. Garnet varies from absence to richness and at times penetrates the plagioclase in peculiar, fingerlike growths. The wall rock has been analyzed by George Steiger and the ore by W. F. Hillebrand with the following results. In the recasting of the rock the results involve no unusual assumptions, but in the ore all the silicates and the spinel are based on an estimate of the distribution of the bases. The other minerals involve no assumptions.

	Rock	Ore		Rock	Ore
SiO_2	44.77	11.73	Cl	......	.12
TiO_2	5.26	12.31	F	......	tr.
Al_2O_3	12.46	6.46			
Fe_2O_3	4.63	30.68	Total	100.75	99.19
FeO	12.99	27.92	Fe	......	44.19
NiO.CoO	tr.	n.d.	Sp. Gr.	3.09	4.138
MnO	.17	n.d.			
MgO	5.34	3.35	Ilmenite	9.73	22.95
CaO	10.20	3.95	Magnetite	6.73	44.31
BaO	tr.	n.d.	Pyrrhotite	.65	.09
K_2O	.95	.26	Apatite	.67	1.74
Na_2O	2.47	.50	Olivine	2.93	7.33
H_2O	.60	.64	Pyroxene	32.71	5.01
P_2O_5	.28	.82	Plagioclase	37.36	12.53
V_2O_5	n.d.	.04	Orthoclase	5.00	......
CO_2	.37	.32	Kaolin	3.60	......
S	.26	.04	Calcite	.90	......
C	n.d.	.05	Spinel	......	3.55

In the quantitative system the rock comes under class III, Salfemane, order 5, Gallare, rang 4, Auvergnase, subrang 3, Auvergnose. The ore falls in class IV, Dofemane, order 4, Adirondackare, suborder 2, Adirondackore, rang 1, Adirondackase.

The above is unusually high in apatite for ore of this variety. It is also remarkable in yielding a very small amount of free carbon, as to the condition of which in the ore one can only surmise. Graphite would be the most probable mineral.

Oak Hill pit. In speaking of the Ross pit upon an early page, it was remarked that an apparently titaniferous ore had been opened higher up on the hillside. The locality is approximately a mile north of New Russia, on the western side of the highway. A specimen yielded W. F. Hillebrand the following results, which have been recast for the mineralogy. The ore is low in TiO_2 but

it has a remarkably high percentage of chlorine, leading one to suspect the presence of scapolite, as was suggested by Dr Hillebrand. A trace of carbon was found in this sample recalling the results just stated under the Lincoln Pond pit.

The Oak Hill pit is a small one, in gabbro like the others.

Oak Hill ore

TiO_2	5.21	Ilmenite	9.70
FeO	22.81	Magnetite	44.08
Fe_2O_3	30.34	Pyrrhotite	.09
SiO_2	21.42	Olivine	11.44
Al_2O_3	7.03	Pyroxene	10.47
MgO	6.92	Plagioclase	20.04
CaO	3.59	Orthoclase	2.22
K_2O	.41		
Na_2O	.53		
H_2O	.95		
P_2O_5	.14		
S	.04		
Cl	**.42**		
Total	99.81		
Fe	38.98		

In the quantitative system this ore has the same series of names as the one last mentioned from Lincoln pond.

Titaniferous ores in Moriah. The presence of a titaniferous body near Cook shaft, north of Mineville, but actually in Elizabethtown has been earlier remarked. The possibility of the presence of titanium in the Craig harbor bed has also been suggested. Besides these, however, several occurrences have been mentioned to the writer by Mr S. Lefevre, chief engineer of Witherbee, Sherman & Co. Specimens have been brought in from time to time to Witherbee, Sherman & Co., for analysis, but the writer has not seen the occurrences in the field. Little if any work had been done upon them, so far as known, and while in the field, they were not noted. The bodies are liable to appear in any of the gabbro areas.

West of Mineville is Mt Tom on whose western side is a highway which is prolonged in a trail to Newport pond. An occurrence is reported somewhere near this trail.

Another occurrence has been reported about a half mile due north of Feeder pond, in the southwestern shoulder of the hill reaching 1640 feet.

About 2½ miles west of Moriah Corners (or Moriah on the map), a highway turns due south, and at ¾ of a mile bends sharply

to the east. In the hills somewhere southwest of this angle of the highway another occurrence has been reported.

Commercial value of the above titaniferous ores. So much interest has been felt in the exposures of these ores that a few remarks should be made upon their commercial values. Enough analyses are now in hand to illustrate in a satisfactory manner what may be expected. The percentages in iron, titanic oxid, phosphorus and sulfur may be first summarized, with the name of the sampler.

	Fe	TiO_2	P	S
Split Rock, J. F. Kemp	32.82	15.66	.017	.14
Split Rock, G. W. Maynard	32.59	14.70		
Tryan pit, J. F. Kemp	24.65	10.55	.20	.10
Tunnel mountain, J. F. Kemp	35.99	16.42	.009	.09
Little pond, J. F. Kemp	41.57	18.82	tr.	.06
Little pond, J. F. Kemp	29.87	13.07	.14	.10
Lincoln pond, J. F. Kemp	44.19	12.31	.36	.04
Oak hill, J. F. Kemp	38.98	5.21	.06	.04
Kingdom Works, G. W. Maynard	32.59	13.15	......	......
Iron mountain, J. F. Kemp	40.42	16.37	......	......

It is at once apparent that all these ores are extremely low grade, the richest being 44.19 and only two others reaching 40. Since under present conditions and those which are likely to continue for many years, no magnetite under 50 per cent in iron is of importance as a source of lump ore, unless it should have exceptional purity in phosphorus and sulfur, be lacking in titanium, and be in addition located near a furnace, there is little encouragement to look with favor upon bodies of this type.

The percentages in phosphorus and sulfur are also important features. In sulfur the ores are obviously low. In phosphorus they are variable. In instances such as Split Rock, and Tunnel mountain, they are very low; in others they are quite high as at Lincoln pond. There is a somewhat widely prevalent impression that the titaniferous ores always run low in phosphorus and sulfur but this is clearly unjustified. As with other ores each case must be sampled by itself.

The presence of vanadium in these ores is a matter of much scientific interest and since the element has come into such extended use for high grade steels some have looked to the titaniferous ores as possible sources. If we summarize the results given above, we obtain:

	V_2O_5		V_2O_5
Split Rock	.55	Lincoln pond	.62
Tryan pit	.34	Little pond	.50
Tunnel mountain	.61	Little pond	.04

In just what form the vanadium is combined is unknown. From its chemical properties similar to phosphorus one would suspect some compound analogous to apatite, just as we have pyromorphite and vanadinite, but although the vanadic oxid exceeds in amount the phosphoric the mineral containing it has never been isolated.

Ferro-vanadium is manufactured from vanadium compounds by electrical processes and contains about 25–27 per cent of this element. It would appear as if the percentage of this valuable substance were too low to make it a serious factor in the value of the ore, but as the industry of vanadium is as yet in its infancy one should speak regarding the future in a conservative spirit. In vanadium steel, now so highly prized for its toughness, there is much less than one per cent vanadium. Elementary vanadium constitutes 77.4 per cent of vanadic oxid (V_2O_5).

Magnetic iron ores under 50 per cent and not fulfilling the conditions stated above, must undergo magnetic concentration if they are to be utilized. It is with regard to this method of treatment that the recasting of the analyses into percentages of ilmenite and magnetite has especial significance. The magnetite would be the mineral saved and the one upon which efforts would be especially expended. The iron in the ilmenite we would expect if not hope to lose, so as to reduce the titanium. The iron in the pyroxene and olivine would pass off in the nonmagnetic tailings. So far as iron is concerned we are therefore reduced to considering alone the magnetite and therefore the following tabular summary is presented.

	Ilmenite	Magnetite	Iron in magnetite
Split rock	29.42	22.97	16.63
Split rock	27.95	32.8	23.74
Tryan pit	25.34	16.71	12.10
Tunnel mountain	30.80	29.80	21.58
Little pond	35.27	38.05	27.55
Little pond	24.49	16.24	11.76
Lincoln pond	22.95	44.31	32.08
Oak hill	9.70	44.08	31.91
Kingdom Works	24.64	31.08	22.50
Iron mountain, Elizabethtown	30.80	35.73	25.86

These results show that even if the ilmenite and magnetite are so coarsely intergrown as to make a separation feasible, the grade of the ore is too low to make the separation a likely source of profit. On the other hand the ore is extremely hard and fine grained, quite different from the richer and more coarsely crystalline occurrences at Lake Sanford and parallels can not be justly

drawn. While the concentrates would doubtless be somewhat enriched in iron by ilmenite which would enter them, they would be decreased by some inevitable losses in magnetite, and by just so much as the titanium exceeded a very small value, say one per cent, the operators of iron furnaces under present slag calculations would regard them unfavorably.

The conclusion is quite irresistible that only by smelting in the crude or lump form, and by the development of a process which does not find titanium objectionable, and under conditions where ores of iron content of 35-45 could be utilized, can these deposits be made available. Regarding the smelting of these ores, the following papers by Mr A. J. Rossi should be consulted by any one interested. *Titaniferous Ores in the Blast Furnace* [Am. Inst. Min. Eng. Trans. 1893. 21:832]; *The Smelting of Titaniferous Ores* [The Iron Age. Feb. 6, 20, 1896].

c Red hematite

There is but one locality for this mineral and it is one of no more than scientific importance. On the south side of McKenzie brook, just west of the highway running south along the shore from Port Henry, a series of pits was dug years ago upon a red outcrop which suggested ore. The red color is due to hematite which has developed as a decomposition product along a line of faulting and crushing. The country rock is a basic member of the syenite series and the fault runs about n. 70° w. nearly parallel with the present brook. The decomposition of the pyroxene or hornblende has apparently yielded the red hematite, just as from similar causes certain portions of the richly apatitic ore at Mineville are stained red. The present dumps along McKenzie brook display very lean and greatly slickensided material and there is little reason to regard the occurrence as more than an interesting case of faulting.

2 Limestone

a **Flux and macadam.** Limestones for these two purposes have been chiefly quarried near Port Henry. For flux in the blast furnaces in former years the Grenville limestones were extensively opened. They furnished a coarsely crystalline variety which was a fairly pure calcite except in so far as this mineral was mixed with disseminated silicates. All through the quarry faces streaks of hornblende schist, bunches and lenses of pegmatite, and finely disseminated pyroxenes often altered to serpentine, are present

in such abundance as to cause much waste. From between them the purer streaks of limestone were selected and used as stock in the furnaces. The rejected dumps now furnish interesting material for the mineralogist, since well terminated crystals at times project into pockets of calcite in such relations that they may be easily freed.

The pure, white limestone is occasionally replaced by the serpentinous variety, ophicalcite, locally called Moriah marble, and this will be again referred to under ornamental stone.

The quarries in the Grenville have been shut down for years, since, although the old Cedar Point furnace is still in vigorous campaign the necessary limestone is elsewhere obtained. The largest of the old quarries is the Pease, just north of Mill brook in the outskirts of Port Henry. An impressive face of limestone is exposed with a large black sheet of hornblende schist capping the top. A half mile farther north and on the northern side of the brook which flows into Craig harbor, is another opening, quite similar in geological relations. A third one lies on the western side of the ridge which separates Mineville from the lake, and is just south of the Pilfershire iron mines on the east side of Barton brook. In this last named quarry is the broken dike or sheet of hornblendic rock, shown in plate 9. There are many other places where this same limestone could be opened up if needed but at present there seems to be no call for the material.

The present source of flux for the furnace is the faulted block of Beekmantown limestone on the lake shore just south of Craig harbor. It furnishes a somewhat silicious, magnesian variety and is broken and carted to the furnace yard as needed. Were other varieties required, the Chazy and Trenton ledges on Crown point would deserve investigation, since the Chazy on Willsboro point is a fairly pure calcite, although it varies somewhat in different beds.

In a small way the Grenville limestones have been quarried and burned for lime in former years. The industry was, however, rather a feature of the earlier and more isolated conditions than those of today. The ruins of an old kiln are still recognizable along the road to North Hudson and about 3 miles west of Moriah Corners. Another one is in the western foot of Woods hill, about a mile north of Elizabethtown. From stray bits of clinker it is probable that one also was in existence near the ledge on the northeastern feeders of Jackson brook.

To a small extent the Beekmantown limestone from the furnace quarry, near Port Henry, has been used for macadam, but there

is no doubt that should road metal of this character be needed in the movement for improved highways, this particular stratum should receive careful attention. While it appears near Port Henry chiefly in the two faulted blocks along the lake, it is present in great amount in Westport, and to the south in Crown Point it covers a rather large area. As it appears, moreover, in the regions of the Champlain clay, where the roads are particularly bad in wet weather, it may be worthy of investigation. Being a hard and as a rule silicious variety it would seem to be best adapted of all the local stone for macadam.

As a natural material for use upon the highways the calcareous sand or gravel, which results from the surface decomposition of the Grenville limestone, has been dug to advantage. It is occasionally available in pockets of sufficient size to yield borrow pits of moderate capacity, and it packs under traffic to a very excellent surface.

b **Limestones for building and ornament.** The Paleozoic strata could furnish limestone suitable for structural purposes if desired, but except in the barracks of the old fort on Crown point, they have not been extensively utilized. The Chazy is the best available for these purposes, because of its heavy bedding, and more uniform character. The remains of the old Crown Point quarry can still be seen, but it has not been much if at all utilized in later years. The Beekmantown is also a rather heavily bedded stratum but is irregular in character and harder for tool treatment. The Trenton strata are as a rule too shaly for extended use.

The one ornamental stone within the area here described is the serpentinous marble which appears in several localities in the Grenville series. It has also been used for walls in the village of Port Henry. The more abundant white crystalline limestone is occasionally replaced by beds which are mottled with green serpentine, affording when the mottling is regular and not too coarse, a very beautiful ornamental stone which was formerly placed on the market as verd-antique or Moriah marble. The difficulty in the industry is the irregularity of the serpentine, which at times is in large masses and again in small, shotlike disseminations.

There are three points at which the stone has been taken out. One, the Treadway quarry, is on the brook which flows into Craig harbor, just north of Port Henry and near the point where the fork is shown at its headwaters. A ledge 10 or 15 feet thick was here channeled out in former years but has not been worked for

at least 20 years past. Another quarry is next the highway a quarter mile north of the Cheever mine. A third, the Reed quarry, is in western Moriah just southeast of Broughton ledge and in the curious loop made by the brook which rises at its foot. This last named opening has been more recently worked than the others. The petrography of these rocks has been discussed in the general treatment of the Grenville.

3 Clay

The Champlain clays are very generally present upon the flat Paleozoic strata wherever these appear in the larger areas along the lake shore. The clays constitute the surface over the larger partion of the peninsula of Crown point and are widespread in Westport. Should they be needed in the future as the raw materials of brick they could be furnished in any desirable amount. Up to the present the industry is practically undeveloped and these resources may be considered as reserves. It is probable, that like the similar clays elsewhere they would furnish a good grade of ordinary red brick. The sand for tempering would of necessity be sought in the higher terraces along the Archean front, where the deltas and water-sorted drift contain it. Judicious search would undoubtedly serve to locate the sand and clay in proximity with each other.

Chapter II

MINERALOGY

The area of the Elizabethtown and Port Henry quadrangles presents some localities of special interest to the student and collector of minerals. It is therefore of interest to embody in a special chapter the notes and experience gained while in the field. The minerals may be classed under three or four heads on the basis of association as follows, but it is not intended to include in the list the ordinary rock-making minerals or others which do not exhibit some feature of special interest. The list amplifies in some respects the one given by the writer in the *Geology of the Magnetites near Port Henry, N. Y.* [Am. Inst. Min. Eng. Trans. 1897. 27:195].

1 Minerals of the Paleozoic limestones, embracing occasional calcite crystals and one occurrence of sulfur, derived from the alteration of pyrite.

2 Minerals of the Grenville limestones, and their associated inclusions of silicates, viz: calcite, diopside, fluorite, garnet, graphite,

hornblende, orthoclase, quartz of the rose variety, phlogopite, plagioclase, rutile, titanite, tourmaline, wernerite, wollastonite.

3 Minerals of the nontitaniferous iron mines. These are of two groups, according as they occur in the ore or in the associated pegmatites or pegmatitic segregations. In the ore proper, there is little beyond magnetite, apatite, calcite, hematite, molybdenite, and siderite, deserving comment and most of these are unusual. The interesting minerals are in the pegmatites and the list is quite large, albite, allanite, amphibole, apatite, arsenopyrite, biotite, fluorite, garnet, lanthanite, magnetite, molybdenite, pyrite, pyroxene, quartz, titanite, wernerite, zircon.

4 Minerals of the titaniferous iron deposits, ilmenite, magnetite.

The above species will now be taken up in alphabetical order with comments on the occurrence.

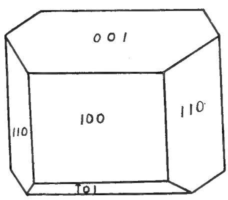
Albite. In 1895 or 1896 the workings in the great pit of Mine "21," encountered a large and coarsely crystalline pegmatite dike. Many carloads of this rock were brought to the surface, of which a comparatively small part is still accessible in the easternmost dump along the main track toward Port Henry. From the pegmatite, cleavage masses of striated and slightly greenish feldspar can sometimes be obtained. Cleavage flakes parallel with the base, give an extinction from parallelism to 3 degrees. On the brachypinacoid the extinction reaches 15 degrees. Prof. William Hallock determined the specific gravity of a piece weighing about 55 grams to be 2.6182 at 14.5° C. This is slightly below the general average (2.62) of albite, but undoubtedly the albite molecule predominated in the piece. Still the general appearance, depending as it does on the greenish hue and the coarse striations, reminds one rather of oligoclase.

Allanite. This mineral, usually esteemed a rare one, is present in unusual amount and has afforded some crystals of exceptional size and perfection. Allanite from this locality was first announced by W. P. Blake in the *American Journal of Science*, September 1858, page 245. The occurrence was in the Sanford bed, or as we now call it, the "Old Bed," the one just north of "21" and at present not much worked. Allanite crystals 8 or 10 inches long, 6 or 8 inches broad, and ½ inch thick are cited. The particular rock mass containing them was apparently long since exhausted, but one may still find small allanites in the pegmatitic streaks of this old pit. James Hall secured one of the large and very perfect ones in the early days and placed it in the hands of E. S. Dana by whom it was described in the *American Journal of Science* for

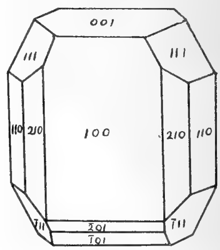
June, 1884, page 479. The specimen was formerly in the Yale collections and it certainly is an unusually fine crystal.

In later years the workings in the Smith mine, through the Cook shaft have brought up much coarse pegmatite in which there are at times great quantities of large allanites, some of which almost equal the dimensions given above. They are not always, or not very often well terminated, and being embedded in quartz and feldspar, and being withal extremely brittle they require great care and patience for their safe extraction. A series of the best secured by the writer were placed in the hands of Heinrich Ries in 1898, and were by him figured and described in the *Transactions of the New York Academy of Sciences,* volume 16, pages 329-30, 1898. The two figures, drawn by Dr Ries are here reproduced.

31



32



Figs. 31, 32 Allanite crystals from Cook shaft of Smith mine, Mineville (after Heinrich Ries)

Amphibole. The most attractive member of this group is a light brown variety which is occasionally well developed in the quarries in the Grenville, north of Port Henry. The crystals up to an inch in length by a half inch in the long diameter have grown from bunches of silicates into a cavity which has afterward been filled with calcite. When the latter is dissolved away, the former remains in almost perfect development. A sharp prism and both the orthopinacoid and clinopinacoid make up the vertical zone, and the terminal faces are a pair of pyramids.

Dark green or black amphibole is common in the coarse pegmatitic aggregates associated with the magnetites on Barton hill. Where it abuts against quartz, it develops the face of the unit prism, but as a rule only cleavage pieces can be obtained.

Apatite appears in great quantity in the rich phosphorus ores of the Old Bed series at Mineville. The grains may reach a quarter of an inch in diameter and are usually of a red color from infiltrated hematite. They impart a red color to the ore itself and thus produce the variety known as red ore. This variety of apatite is separated in the mill and sold for fertilizer.

In the pegmatitic aggregates from the Barton Hill mines, apatite appears in green hexagonal prisms, up to half an inch in diameter. It has also been noted as an inclusion in titanite, having preceded this mineral in time of formation. The angles of the crystals are more or less rounded as so often happens with this mineral.

Arsenopyrite is of rare occurrence in the coarse pegmatite of the "21" mine. It is associated with quartz, orthoclase, albite and zircon. Although as a rule in thin seams long cracks and cleavage planes, one specimen was found, about ½ inch long, by ⅛ inch broad and thick. It had, however, but one crystal face.

Biotite occurs in the coarse pegmatitic aggregates of the iron mines, and in the bunches of silicates in the Grenville limestone quarries. It seldom exhibits crystal boundaries.

Calcite. This mineral is of course present in the Grenville limestone quarries and is occasional in the mines at Mineville. The most interesting occurrence is one discovered in 1888 by Mr W. H. Benedict, then principal of the Port Henry High School. The crystals were measured and figured by the writer in a brief note in the *American Journal of Science* for July 1890, page 62, and the figure is reproduced in the 6th edition of Dana's *System of Mineralogy*. Upon the faces of the unit rhombohedron, with subordinate 4R, are superimposed two scalenohedrons whose combination oscillating with R builds up a low, four-sided pyramidal form. The two scalenohedrons gave $\frac{3}{7}$ R $\frac{9}{5}$ and $\frac{13}{11}$ R $\frac{9}{7}$

At Mineville the calcite appears in crusts consisting of well developed $-\frac{1}{2}$ R. The Miller pit has furnished the best specimens but they are not common.

Diopside, *see* under Pyroxene.

Feldspar. Albite has already been noted above. Oligoclase in great cleavage pieces has been collected from the old Cheever mine dumps and exhibits especially fine striations. Similar cleavage pieces may often be obtained from the pegmatitic masses of the other mines. Labradorite is in endless quantity in the anorthosites. In the mountains along the Schroon valley it can be sometimes obtained in fairly good pieces, but as a rule throughout the area, the anorthosites have been so excessively granulated as to destroy the larger crystals. Orthoclase is common in the pegmatites but is seldom well crystallized. Yet in the area just south in Crown Point huge and well developed orthoclase crystals occur.

Fluorite of massive character and not displaying other than cleavage faces ccurs in great abundance in the Barton Hill ore bed. The new tunnel which has been recently run from the Arch

pit, so as to tap the lenses in depth, has cut large pockets of it, enough to form the entire wall on one side. The fluorite is white and has disseminated magnetite. It is near the lower workings of the Lovers pit. When this pit was in active operation it encountered a peculiar, dense, green rock in small amount which, the microscope showed, consisted of quartz and actinolite. It contained scattered masses of fluorite of pink and green colors and up to 2 inches in diameter.

The most interesting fluorite of all, was however by chance obtained in one of the quarries in the Grenville limestone just north of Port Henry. A rather insignificant crust of dull yellowish color, proved to be this mineral, filled with the wormlike growths, technically called "helminths." The commonest helminths are chlorite in quartz, but of what those in the fluorite consist is not known.

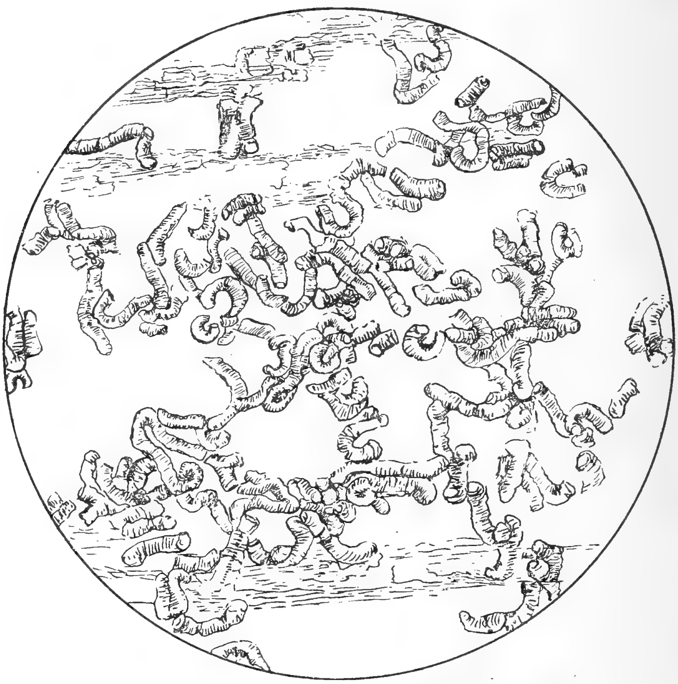


Fig. 33 Helminths of some unknown mineral in fluorite. Actual field about .05 inch

Garnet occurs in the North and South pits on Barton hill in excellent rhombic dodecahedra which are at times distorted so as to be greatly flattened. Aside from this occurrence well crystallized garnets have not been observed, but massive specimens of the mineral are not uncommon in both anorthosites and basic

syenites. In the sedimentary gneisses they also do not fail, and at times are very abundant. They are rich in the hill just east of Moriah Center and north of the Port Henry road and are of a pale pink. The commoner variety in the other rocks is deep red.

Graphite is widespread in the Grenville limestones and in the thin associated quartzites, but does not seem abundant enough to mine in any observed locality. In the quarries north of Port Henry and in the coarsely crystalline calcite it sometimes exhibits sharp hexagonal crystals of diameters a quarter of an inch and less. In the pegmatite streaks it is coarser, but is seldom regular in outline.

Hematite, pseudomorphic after magnetite occurs in the pegmatite of the "21" mine. It is really martite, and retains the shape and cleavage of magnetite, while having a red streak. Some tabular masses of specular ore were met years ago at Fisher hill and were given the writer by E. B. Durham E. M., then engineer for the mining companies.

Hornblende, *see* Amphibole.

Hypersthene, *see* Pyroxene.

Ilmenite appears of massive character mingled with magnetite in the titaniferous ore bodies, but thus far no good crystals have been discovered. These ore bodies are almost barren of good crystals.

Jasper has been afforded by a little vein in the Miller pit, Mineville. The quantity was small.

Lanthanite was found in 1858 by W. P. Blake in association with the large allanites of the Sanford pit, Mineville, now called Old Bed. It formed small crystalline plates and probably resulted from the alteration of the allanite [Am. Jour. Sci. Sept. 1858. p. 245].

Magnetite possesses especial interest not only from the great quantity which is available for mining but because in a large lense of ore developed in the early nineties in the Lovers pit slope of the Barton Hill mines, remarkably perfect crystals of this mineral appeared. The containing ore to the amount of 40,000 tons averaged over 68 per cent iron and carload lots ran 72. The crystals were buried in the granular ore and, as this crumbled readily, they were easily freed. While the greater number were more or less imperfect from the interference of neighboring crystals or granules with their growth, there were found from time to time others up to an inch on the edge of the octahedron which were almost perfect. The faces of practically all the crystals are smooth and brilliant. The common forms were the octahedron with the rhombic dodec-

ahedron modifying the edges. Locally and at the time of production for many miles up and down the Delaware and Hudson Railway the crystals were known as "diamonds." During visits to the mine the writer made a careful study of hundreds and endeavored to detect other faces, freely using the reflecting goniometer in the measurements; but all the determinations led to such extraordinary indexes and to such variable results that the faces were believed to be merely interference planes produced by contact. The plane faces were found to be traversed by regular series of striations most of which follow the octahedral parting planes, but others are parallel to still other faces as described in the reference below to the writer's paper on "Gestreifte Magnetitkrystalle."

The finest of all the crystals of magnetite from Mineville is preserved in the office of Witherbee, Sherman & Co. at the mine and is about an inch in diameter. It is almost a mathematically perfect octahedron, having only one slight interference plane on one apex. Fortunately the matrix is also preserved but the crystal is believed to have come from the Old Bed (or Sanford) pit.

All the pits are from time to time sources of cleavage pieces bounded by octahedral planes and often of large and regular size. The apparent cleavage is, however, really due to a series of parting

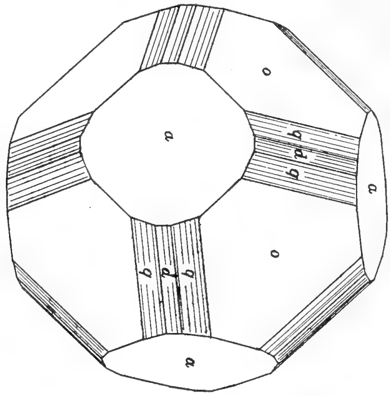


Fig. 34 Magnetite crystal from the Split Rock mine

planes or gliding planes as is usually believed to be the case with minerals of the spinel group. Rarely these plates exhibit brilliant luster.

In the coarse pegmatite of the "21" pit, moderately large but very fragile crystals of magnetite are not uncommon, which are dodecahedral forms built up of octahedral triangular planes, a very common feature of magnetite.

In the dump of the Split Rock titaniferous ore body the writer happened upon a few pieces, which had once formed the sides of a narrow crevice. They were coated with small but brilliant crystals which Mr H. P. Whitlock of the State Museum identified as magnetite of the form shown by the accompanying figure which he kindly drew. The crystals are remarkable for the development of the cube, a rare face in magnetite, and for the trigonal trisoctahedron.

The following papers have dealt with the magnetite crystals from Mineville:

Birkinbine, John. Crystalline Magnetite in the Port Henry, N. Y. Mines. Am. Inst. Min. Eng. Trans. 1890. 18:747.

Kemp, J. F. Gestreifte Magnetitkrystalle aus Mineville, Lake Champlain Gebiet, Staat New York, Zeitschrift für Krystallographie, 19:183. Notes on the Minerals occurring near Port Henry, N. Y. Am. Jour. Sci. July, 1890, p. 62.

Microcline, *see* under Feldspar.

Molybdenite, as is usual in the magnetic mines of the ancient gneisses, occasionally appears in the pegmatitic streaks. In the New Bed pits it has been observed as scales associated with pyrrhotite.

Olivine is a common constituent of the gabbros but seldom if ever in amounts sufficient to see without the microscope.

Phlogopite appears in the quarries in the Grenville limestones and ophicalcites, its characteristic association.

Plagioclase, *see* under Feldspar.

Pyrite is a rarity in the large mines and is only met in some secondary veinlets. It does appear in some of the smaller and leaner ore bodies but not, so far as known, in good crystals.

Pyroxene being the name of a group, the several species under it must be taken up separately. Hypersthene, the orthorhombic member, is common in the anorthosites and gabbros, usually in the microscopic way; but when the former are coarsely crystalline and above all pegmatitic, the hypersthene assumes moderately coarse, platy growths which give cleavage pieces.

Diopside appears in the quarries in the Grenville limestones. Once at the ophicalcite quarry a half mile north of Port Henry, the writer happened on pockets of calcite, into which diopside, brown hornblende and titanite projected in such a way as to be easily freed by weak acid. The diopsides vary from one tenth to half an inch in length and possess shining faces adapted to goniometrical measurement. They are usually white but shade to pink and are translucent. They have been measured and figured

by Dr Henirich Ries in his valuable paper on the "Pyroxenes of New York State," Annals of the New York Academy of Sciences, volume 9, page 171 and figures 9 and 10 on plate 14. They have yielded eight or ten of the faces found on the more complicated pyroxene crystals. Dr Ries analyzed the crystals with the results given under column 1 below. The specific gravity is 3.27.

Much careful study has been given by Dr George P. Merrill to the diopside masses from which the serpentine of the ophicalcites has been derived. An unaltered nucleus was separated by him and analyzed with the results in column 2. The serpentine is given in column 3. The two analyses of the diopside are strikingly alike.

	1	2	3
SiO_2	54.57	55.26	42.17
CaO	23.25	24.48	....
MgO	17.78	19.53	41.33
FeO	1.80	.57	.64
MnO	......	tr	....
K_2O	.70	....	....
Al_2O_3	1.12	.22	.30
Fe_2O_3	....	.22	1.57
Ign	.38	....	....
H_2O	....	....	13.72
Total	99.60	100.28	99.73

Each of these is almost pure diopside (CaMg)O. SiO_2. The serpentine evidently results from the disappearance of the lime and some of the silica, and the assumption of water.

In association with the iron ores and especially in the pegmatitic streaks involved in them crystals of black augite occasionally appear. One of these gathered by the writer at the Cheever mine has been figured by Dr Ries in figure 8, plate 14 of his work just cited. An analysis yielded

SiO_2	FeO	CaO	MgO	Al_2O_3	Fe_2O_3	Total
49.12	15.98	17.30	6.06	7.49	3.53	99.48

Specific gravity 3.60

From the presence of the sesqui-bases this is obviously an augite.

In the ore of the Old Bed group at Mineville a pyroxene of an emerald-green color is frequent, and is similar to the one in the neighboring syenitic rocks. Its color strongly suggests that it is related to aegirite and that it contains the soda-iron molecule in large amount.

Pyrrhotite is rare in the larger mines although seen in some of the smaller sulfurous ones. It is not uncommon in the bunches

of silicates in the Grenville limestone quarries and occasionally yields platy crystals suggestive of its characteristic forms but too rounded for sharp determination.

Quartz. The large mines have yielded a few good quartz crystals of the smoky variety. The pegmatites have corroded and rounded dihexahedrons. The most interesting occurrence is, however, the rose quartz which is obtained in pits just west of the road from Port Henry to Cheever and about a mile and a half from the former. The color is very beautiful and the amount quite unusual. It forms veins in the Grenville series.

Rutile appears in the bunches of silicates in the quarries of Grenville limestone, in somewhat scarce striated prisms and in irregular fragments.

Scapolite, *see* under Wernerite.

Serpentine appears in masses often of very attractive dark green color in the ophicalcite exposures. An analysis is given above under pyroxene.

Siderite appears in small cross veinlets in the Miller pit. It forms a crust under calcite.

Titanite appears both in the hornblendic masses in the Barton Hill ores and in the bunches of silicates in the Grenville limestone quarries, especially the one just north of Port Henry. On Barton hill they are of large size and beauty reaching 2 inches across. The faces are the usual combination of a steep pyramid and the prism.

Wernerite has been yielded by the upper pits on Barton hill, in very excellent square prisms capped by the low pyramid.

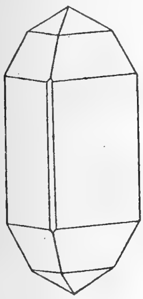


Fig. 35 Zircon crystal from Mine "21"

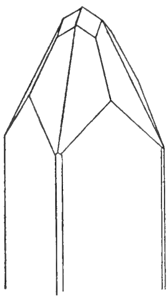


Fig. 36 Zircon crystal from Barton Hill mines

Wollastonite occasionally appears in the Grenville limestones north of Elizabethtown. Its best locality is, however, in the Ausable quadrangle next north.

Zircon occurs in the coarse pegmatite sent up in large quantities from the "21" workings about 13 years ago, and now only available in a few large lumps on one of the dumps. The crystals are of great perfection although of simple forms. 110, 331 and 111 make up the combination. When fresh they are a dark mahogany brown, but some sort of alteration has changed the outer portions of many crystals to an earthy, green and very tender material. The crystals vary in size up to an inch long and three eighths thick. Around them in the matrix are the usual radiating strain cracks. In the hornblendic masses from the dumps on Barton hill, one may rarely obtain small but brilliant zircons consisting of the prisms of the two orders, capped by the zirconoid and the unit pyramid. Figures of each of these are given on page 161 which were kindly drawn by Prof. C. H. Smyth.

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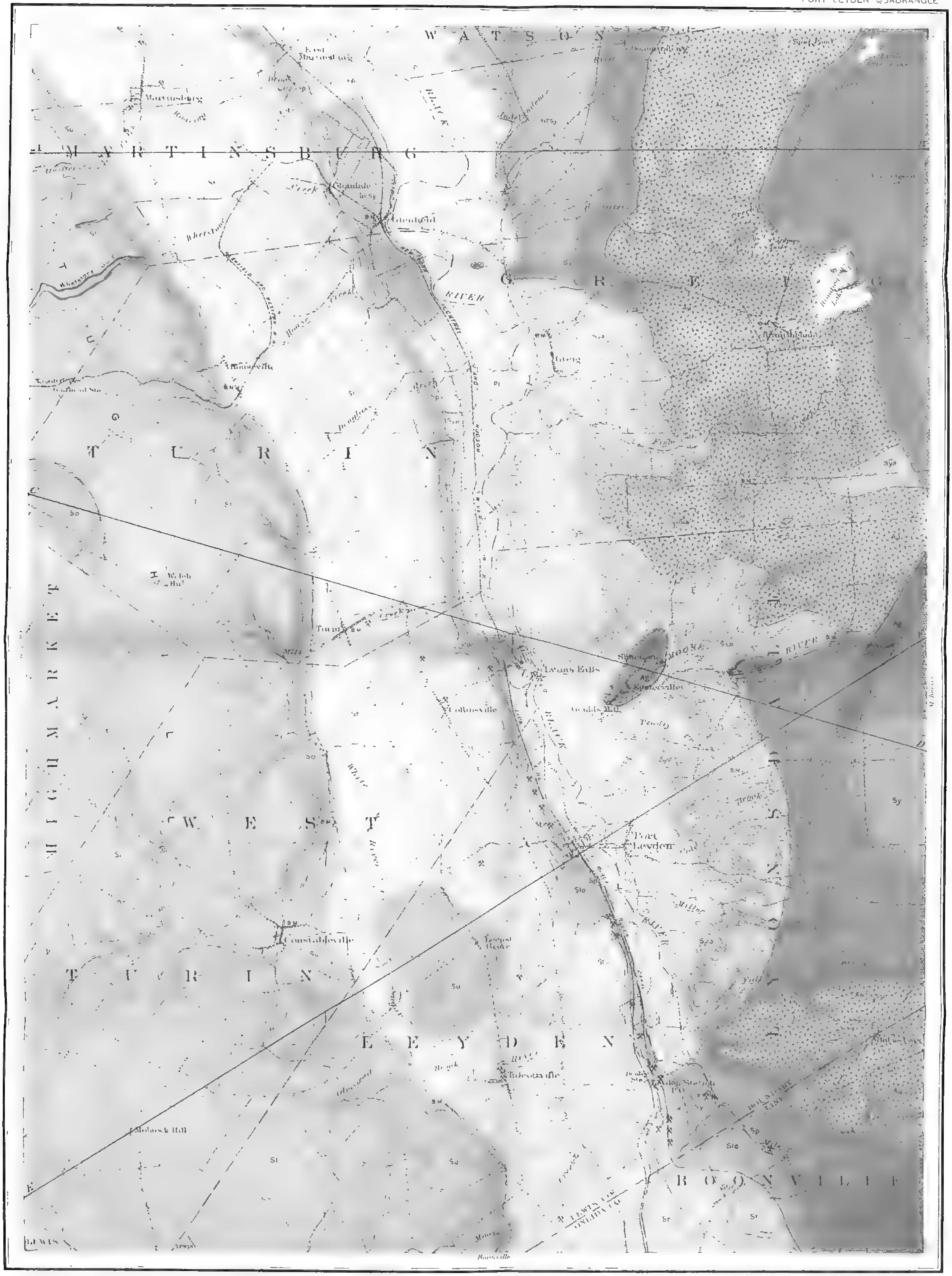
Geologic map of the Port Leyden quadrangle

MUSEUM BULLETIN 137

Geologic map of the Auburn-Genoa quadrangles

MUSEUM BULLETIN 138

Geologic maps of the Elizabethtown and Port Henry quadrangles



LEGEND

Sedimentary Rocks

Pl

Modern valley alluvium together with much Glacial drift

Sands and gravels, mostly delta deposits, and largely concealing boundaries

PLEISTOCENE

So

Oswego sandstone Gray, fine-grained, thin-bedded sandstone.

UPPER SILURIC

Sl

Lorraine shales and sandstones Alternating thin beds of gray to black shales and gray, fine grained sandstones

Su

Utica black shale. Somewhat calcareous toward base.

Str

Trenton limestone. Mostly impure and thin-bedded in lower portion, and crystalline and heavy-bedded in upper portion

Sbr

Black river limestone Pure, bluish gray, massive bluestone with chert nodules and a little shale

Slo

Lowville limestone Pure, bluish, dove-colored, thin to thick bedded limestones, containing calcite filled tubes.

Sp

Pamelia limestone Impure, whitish-gray to bluish gray, sandy limestones Sandstone and conglomerate at the base.

LOWER SILURIC

Metamorphic Rocks

Sy

Syenite. A rather quartzose rock, showing a gneissic structure and of undoubted igneous origin Younger than the Grenville

Grsy

Granitic syenite. A very quartzose phase of the normal syenite gneiss The rock is usually red, straight-banded, and contains long, narrow amphibolite inclusions

Ag

Grenville gneisses Highly metamorphosed, sedimentary rocks, showing a distinct gneissic structure

Syg

Syenite Grenville mixed gneisses. Clearly gneissoid rocks of various types, but mostly Grenville, much cut up by intrusions of syenite

Au

Precambric rocks, but of unknown character because buried under heavy Glacial drift

PRECAMBRIC

Stone Quarries

A B, C D, and E F are structure section lines See text page 18

TOPOGRAPHY BY U. S. GEOLOGICAL SURVEY
IN COOPERATION WITH THE STATE OF NEW YORK

Scale $\frac{1}{62500}$

Miles

Contour interval 20 feet
Datum is mean sea level

Geology by W. J. Miller
1908

EDUCATION DEPARTMENT
JOHN M. CLARKE
STATE GEOLOGIST

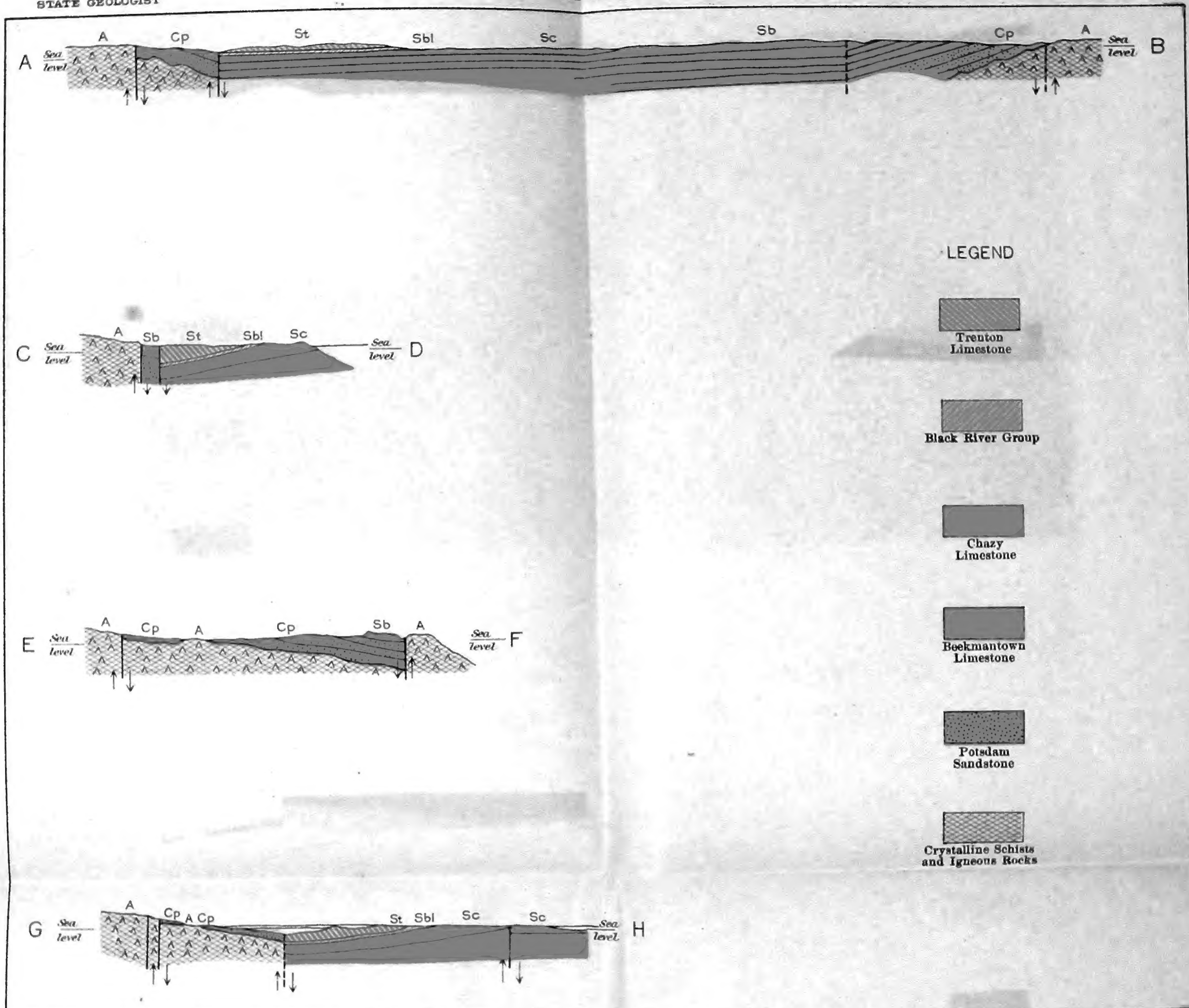
UNIVERSITY OF THE STATE OF NEW YORK
STATE MUSEUM

BULLETIN 137
AUBURN-GENOA QUADRANGLES

Topography by J. H. Jennings and James McCormick
Surveyed in 1899 in cooperation with the State of New York

Scale
Contour interval 20 feet

Geology by D. D. Luther
1908.



SECTIONS ALONG LINES INDICATED ON THE GEOLOGIC SHEET